This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ELECTRICAL

RULES, TABLES, TESTS

AND

FORMULÆ,

BY

ANDREW JAMIESON, C.E., F.R.S.E.

FULLY ILLUSTRATED.

NEW YORK:
THE INDUSTRIAL PUBLICATION COMPANY,
1889.

Eng 4938.89

HARVARD COLLEGE LIBRARY
BY EXCHANGE

DEC 28 1939

ELECTRICAL
RULES, TABLES, TESTS
AND
FORMULÆ.

CONTENTS.

SECTION I.—Formulæ of the Absolute Units, Practical, Electrical, Mechanical, Heat, and Light Units, . , . . 2
" II.—Electro-Chemical Equivalents, Electrolysis, Heat, and Energy of Combustion, ... 5
" III.—Practical Methods of Electrical Measurements, . . 8
" IV.—Electric Conductors, Copper, &c., ... 21
" V.—Insulators, Guttapercha, &c., ... 28
" VI.—Batteries, ... 34
" VII.—Submarine Cables, ... 38
" VIII.—Aerial Land Lines, ... 54
" IX.—Electric Lighting and Transmission of Power, . . 59

§ I.—*a.* FORMULÆ OF THE ABSOLUTE UNITS.*

1. *Fundamental Units.*

Centimetre for Length. Gramme for Mass. Second for Time.

$$\left.\begin{array}{ll}\text{Length in Centimetres} & = \mathrm{L} \\ \text{Mass in Grammes} & = \mathrm{M} \\ \text{Time in Seconds} & = \mathrm{T}\end{array}\right\}\text{C.G.S. System.}$$

2. *Derived Mechanical Units.*

Velocity ... $\mathrm{V} = \dfrac{\mathrm{L}}{\mathrm{T}}$

Force ... $\mathrm{F} = \dfrac{\mathrm{L\,M}}{\mathrm{T}^2}$

Work ... $\mathrm{W} = \dfrac{\mathrm{L}^2\mathrm{M}}{\mathrm{T}^2}$

3. *Derived Magnetic Units.*

Strength of the Pole of a Magnet . $m = \mathrm{L}^{\frac{3}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1}$

Moment of a Magnet . $m\,l$† $= \mathrm{L}^{\frac{5}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1}$

Intensity of a Magnetic Field . . $\mathrm{I} = \mathrm{L}^{-\frac{1}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1}$

4. *Electro-Magnetic System of Units.*

Quantity of Electricity . . . $\mathrm{Q} = \mathrm{L}^{\frac{1}{2}}\,\mathrm{M}^{\frac{1}{2}}$

Strength of Electric Current . . $\mathrm{C} = \mathrm{L}^{\frac{1}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1}$

Electro-Motive Force . . . . $\mathrm{E} = \mathrm{L}^{\frac{3}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-2}$

Resistance of Conductor . . . $\mathrm{R} = \mathrm{L}\,\mathrm{T}^{-1}$

Capacity . . . . $\mathrm{K} = \mathrm{L}^{-1}\,\mathrm{T}^{2}$

5. *Electro-Static System of Units.*

Quantity of Electricity . . . $q = \mathrm{L}^{\frac{3}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1} = v\,\mathrm{Q}$‡

Strength of Electric Current . . $c = \mathrm{L}^{\frac{3}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-2} = v\,\mathrm{C}$

Electro-Motive Force . . . $e = \mathrm{L}^{\frac{1}{2}}\,\mathrm{M}^{\frac{1}{2}}\,\mathrm{T}^{-1} = \dfrac{\mathrm{E}}{v}$

Resistance of Conductor . . . $r = \mathrm{L}^{-1}\,\mathrm{T}$ ...... $= \dfrac{\mathrm{R}}{v^2}$

Capacity . . . . . $k = \mathrm{L}$ ...... $= v^2\,\mathrm{K}$

---

* See "Units and Physical Constants."—*Everett*

† l = length between poles.

‡ $v = 3 \times 10^{10}$ centimetres per second approximatively, and is the ratio of the Electro-magnetic to the Electro-static Unit of Quantity.

5. PRACTICAL ELECTRICAL UNITS OF MEASUREMENT

(*British Association and International Congress of Electricians, Paris*, 1881.)

1. For electrical measurements the fundamental units, the centimetre (for length), the gramme (for mass), and the second (for time), forming the C.G.S. system, are adopted.

2. **Resistance** = (R).—**The Ohm** is equal to 10^9 C.G.S.* units of resistance. It is equal to the resistance of a column of pure mercury 1·0624 metres long, of a square millimetre section, at the temperature of zero Centigrade. The **Megohm** = one million ohms. The **Siemens Mercury Unit** (length 1 metre, section 1 sq. mm. at 0° C.) = 0·94125 ohms.

The above are according to Lord Rayleigh's latest determinations, as given in his letter to the Paris International Conference du Electric Units, Oct. 1882. One mercury unit = 0·95412 of the B.A. unit, and one B.A. unit = 0·98651 of the true ohm.

3. **Electro-motive Force** = (E).—**The Volt** is equal to 10^8 C.G.S.* units of electro-motive force, or about 8 per cent. less than the E.M.F. of a standard Daniell's cell. Electro-motive force is equivalent to the difference of potential between two points.

4. **Current** = (C).—**The Ampere** is equal to 10^{-1} C.G.S.* units of current. It is the current produced by a volt through an ohm.

$$\text{Ohm's Law...Current} = \frac{\text{Electro-motive force}}{\text{Resistance}}, \text{ or } C = \frac{E}{R}.$$

5. **Quantity** = (Q).—**The Coulomb** is equal to 10^{-1} C.G.S.* units of quantity. It is the quantity of electricity given by an ampère in a second.

6. **Capacity** = (K).—**The Farad** is equal to 10^{-9} C.G.S.* units of capacity. It is the capacity defined by the condition that a coulomb charges it to the potential of a volt.

A microfarad = (*mfd.*) = 10^{-15} C.G.S.* units of capacity, or one-millionth of a Farad.

† 7. **Power** = (P).—**The Watt** is equal to 10^7 C.G.S.* units of power. It is the power conveyed by a current of an ampere through a conductor whose ends differ in potential by a volt; or, in other words, the rate of doing work when an ampere passes through an ohm, and it is equal to 10^7 ergs, or a Joule per second ($\frac{1}{746}$ of a horse-power nearly). $\therefore E \times C = \text{Watts}$, and $\frac{E \times C}{746} = \text{horse-power}$.

† 8. **Heat or Work** = (W).—**The Joule** is equal to 10^7 C.G.S.* units of work or ergs. It is the work done, or heat generated by a Watt

---

* Electro-magnetic system.

† Two units proposed by Dr. Siemens at British Association, 1882, and likely to be adopted in practice.

in a second—*i.e.*, the work done, or heat generated in a second by an ampère flowing through the resistance of an ohm, or the heat generated by a coulomb running down through a difference of potential of 1 volt. It is therefore the amount of heat equivalent to 10^7 ergs. Assuming Joule's equivalent = 42,000,000, it is the heat necessary to raise ·238 gramme of water 1° C., or approximately $\frac{1}{1900}$ of the arbitrary unit now in use of 1 lb. of water raised 1° C.

c. MECHANICAL UNITS.

1. **Acceleration** is the rate of change of velocity, and may be either positive or negative.

2. **Gravity.**—The acceleration of a body falling freely under the action of gravity *in vacuo* is denoted by (g).

The value of (g) in C.G.S. units at any part of the earth's surface is approximately = 981 (at Greenwich = 981·17); or 32·2 foot second units.

3. **Force.**—The C.G.S. unit of force is called *the dyne.* It is the force which, acting upon a gramme for a second, generates a velocity of a centimetre per second.

4. **Work.**—The C.G.S. unit of work is called the *erg.* It is the amount of work done by a dyne working through a distance of one centimetre.

5. **Energy.**—The C.G.S. unit of energy is also called the *erg*; work done being equal to the energy expended.

6. **Work expressed in Gravitation Measure:**

One gramme centimetre = (g) ergs = 981 ergs.
∴ one kilogramme-metre = 100,000 (g) ergs.
One foot-pound = 13,825 (g) ergs,
= $1{\cdot}356 \times 10^7$ ergs = 13·56 million ergs.

7. **The Unit Rate of Working** is one erg per second.

Watt's "Horse-power" = 33,000 foot-pounds per minute = 550 foot-pounds per second = $7{\cdot}46 \times 10^9$ ergs per second = 7,460 million ergs per second. The equivalent electrical energy of a horse-power = $\frac{E \times C}{746}$ (where E = electro-motive force in volts and C = current in ampères).

The French *"force de cheval"* = 75 kilogramme-metres per second = $7{\cdot}36 \times 10^9$ ergs per second = 7,360 million ergs per second.

d. HEAT UNITS

8. **Heat** (H).—The unit of heat is the amount of heat required to raise one gramme of water from 0° to 1° Cent.

9. The mechanical equivalent of heat (see *Proceedings Royal Society*, vol. xxvii., p. 38, by Joule) = 772·55 foot-pounds at the

sea level of Greenwich for each degree Fah. in a pound of water $= 4{\cdot}1624 \times 10^7$ ergs per gramme degree Cent., say 42 million ergs, generally represented by letter (J).

10. The **Heat Generated** in time T (seconds) by a current C through a wire of resistance R is $\frac{C^2 R T}{J} = \frac{E C T}{J}$ (gramme degrees), where $J = 4{\cdot}2 \times 10^7$, and C, R, and E are expressed either in absolute electro-magnetic or electro-static units.

For practical use when C is amperes, R ohms, E volts, and T seconds, the heat generated in time $T = C^2 R T \times 0{\cdot}2405$, or $E C T \times 0{\cdot}2405$ gramme degrees.

e. LIGHT UNITS.

1. **The English unit of light** is the light given out by one sperm candle burning 120 grains per hour; (six candles weighing one pound).

2. **Mr. Vernon Harcourt's** standard flame equals the average of one English standard candle. It consists of an air-gas flame, 2½ inches in height, rising from an opening ¼ inch diameter.

Mixture of air and pentane: 576 volumes of air to one of liquid pentane at 60° Fah., or if both are in form of gas 20 of air to 7 of pentane.

3. **The French unit of light** is the light given out by one Carcel burner, and equals 9·3 English standard candles.

§ II.—ELECTRO-CHEMICAL EQUIVALENTS.

1. ***Quantitative Laws of Electrolysis.**—I. The amount of chemical action is equal at all points of a circuit.

II. The quantity of an ion liberated at an electrode in a given time, is proportional to the strength of the current in ampères.

III. The quantity of an ion liberated at an electrode in one second, is equal to the strength of the current multiplied by the "electro-chemical equivalent" of the ion.

If $\left.\begin{array}{l} C = \text{current in ampères} \\ T = \text{the time in seconds} \end{array}\right\} C.T = Q = \text{quantity in coulombs.}$

z = the electro-chemical equivalent (see Table I. col. 5).

w = the weight in grammes of the ion (or element) liberated; then

$$w = C T z = Q z.$$

The above rules, as may be inferred from law (I.), apply not only to the decomposition in a depositing bath, or outside the battery, but also to that taking place inside the charging battery itself.

---

* See "Magnetism and Electricity," Art. 211, Sylvanus P. Thompson.

2. **Polarisation.**—Whenever an electrolyte is decomposed by a current of electricity, the resolved ions have a tendency to reunite, thus setting up an opposing electro-motive force to the decomposing current. This tendency to reunite is commonly termed "chemical affinity." The electro-motive force of the decomposing current must therefore be greater than that due to the chemical affinity of the resolved ions. For example, when water is decomposed by a current of electricity into its constituent ions, oxygen and hydrogen, the opposing electro-motive force due to the chemical affinity of these two gases is about 1·5 volts; therefore no battery can decompose water unless it has an electro-motive force *at least* greater than 1·5 volts.

3. **Electrolysis.**—If Q = the quantity of electricity passed through an electrolyte in C.G.S. units,

E = the opposing electro-motive force in C.G.S. units,

Z = the electro-chemical equivalent of the ion deposited per C.G.S. unit (see Table I. col. 5),

H = heat of combination in gramme degrees of the ion in question with the other resolved ion (see Table II. col. 3),

J = Joule's equivalent $= (42 \times 10^6)$,

Then the amount of work done $= E\,Q = Q\,Z\,H\,J =$ Joule's.

$$\therefore\ E = Z\,H\,J.^{*}$$

Or, the electro-motive force of any chemical reaction is equal to the product of the electro-chemical equivalent of the separated ion into the heat of combination expressed in fundamental units or ergs.†

The principle and action of SECONDARY BATTERIES depend upon the above laws and rules.

One ampere decomposes ·0000945 gramme of water per second, liberating ·0000105 gramme of hydrogen, and ·0000840 gramme of oxygen.

The amount in grammes of any other ion liberated from an electrolyte in one second by a current of one ampere is given by the electro-chemical equivalent of the ion. The electro-chemical equivalent of any element is found by multiplying its chemical equivalent $\left(\text{or } \dfrac{\text{atomic weight}}{\text{valency}}\right)$ by the equivalent for hydrogen, viz., ·0000105 (see Table I. col. 5).

---

[*] To express E in volts, divide by 10^8.

[†] For example:—In decomposing water we can calculate the opposing E. M. F. that will be set up by the hydrogen tending to unite with the oxygen. By formula $E = Z\,H\,J$ (see Table I. for Z, and Table II. for H and J), $\therefore\ E = {\cdot}000105 \times 34000 \times 42 \times 10^6 = {\cdot}000105 \times 1{\cdot}43 \times 10^{12} = 1{\cdot}5 \times 10^8 =$ C.G.S. units of E.M.F. $\therefore\ \frac{E}{10^8} = 1{\cdot}5$ volts. In the same way we may calculate the opposing E.M.F. set up in charging any secondary battery, or effecting any particular electrolysis.

TABLE I.—TABLE OF ELECTRO-CHEMICAL EQUIVALENTS, &c.

(From Sylvanus P. Thompson.)

1	2 Atomic Weight.	3 Valency.	4 Chemical Equivalent.	5 Electro-chemical Equivalent (grammes per coulomb).*
Electro-positive—				z.
Hydrogen, ...	1·	1	1·	·0000105
Potassium, ...	39·1	1	39·1	·0004105
Sodium, ...	23·	1	23·	·0002415
Gold, ...	196·6	3	65·5	·0006875
Silver.	108·	1	108·	·0011340
Copper (Cupric), . .	63·	2	31·5	·0003307
,, (Cuprose), . .	63·	1	63·	·0006615
Mercury (Mercuric), .	200·	2	100·	·0010500
,, (Mercurose), .	200·	1	200·	·0021000
Tin (Stannic), . . .	118·	4	29·5	·0003097
,, (Stannose), . .	118·	2	59·	·0006195
Iron (Ferric), . . .	56·	4	14·	·0001470
,, (Ferrose), . .	56·	2	28·	·0002940
Nickel, ...	59·	2	29·5	·0003097
Zinc, ...	65·	2	32·5	·0003412
Lead, ...	207·	2	103·5	·0010867
Electro-negative—				
Oxygen, ...	16·	2	8·	·0000840
Chlorine, ...	35·5	1	35·5	·0003727
Iodine, ...	127·	1	127·	·0013335
Bromine, ...	80·	1	80·	·0008400
Nitrogen, ...	14·	3	4·3	·0000490

TABLE II.—HEAT AND ENERGY OF COMBINATION WITH ENRRGY.

(From Everett on Units.)

1 1 gramme of	2 Compound formed.	3 Gramme-degrees of heat produced =(H.)	4† Equivalent Energy. in ergs, =(H.J.)
Hydrogen, . . .	H_2O	34000 A F	1·43 × 10^{12}
Carbon, ...	CO_2	8000 A F	3·36 × 10^{11}
Sulphur, . . .	SO_2	2300 A F	9·66 × 10^{10}
Phosphorus, . .	P_2O_5	5747 A	2·41 × 10^{11}
Zinc, ...	ZnO	1301 A	5·46 × 10^{10}
Iron, ...	Fe_3O_4	1576 A	6·62 × 10^{10}
Tin, ...	SnO_2	1233 A	5·18 ,,
Copper, . . .	CuO	602 A	2·53 ,,
Carbonic oxide, . .	CO_2	2420 A	1·02 × 10^{11}
Marsh-gas, . . .	CO_2 and H_2O	13100 A F	5·50 ,,
Olefiant gas, . .	,,	11900 A F	5·00 ,,
Alcohol, . . .	,,	6900 A F	2·90 ,,

---

* The electro-chemical equivalent in grammes per C.G.S. unit, or Z equal 10 times z, because a coulomb = $\frac{1}{10}$ of the C.G.S. unit of quantity.

† Column 4 is obtained by multiplying the corresponding figures in column 3 by Joule's equivalent (J = 42 × 10^6), since 1 gramme-degree of heat = 42 × 10^6 ergs.

TABLE II.—*continued.*—COMBUSTION IN CHLORINE.

1 1 gramme of	2 Compound formed.	3 Gramme-degrees of heat produced =(H.)	4 Equivalent Energy in ergs =(HJ.)
Hydrogen,	HCl	23000 F T	$9·66 \times 10^{11}$
Potassium,	KCl	2655 A	1·12 ,,
Zinc,	$ZnCl_2$	1529 A	$6·42 \times 10^{10}$
Iron,	Fe_2Cl_6	1745 A	7·33 ,,
Tin,	$SnCl_4$	1079 A	4·53 ,,
Copper,	$CuCl_2$	961 A	4·04 ,,

The numbers in the last column are the products of the numbers in the preceding column by 42 millions.

The authorities for these determinations are indicated by the initial letters A (Andrews), F (Favre and Silbermann), T (Thomsen). Where two initial letters are given the number adopted is intermediate between those obtained by the two experimenters.

§ III.—ELECTRICAL MEASUREMENTS.

a. WHEATSTONE'S BALANCE.

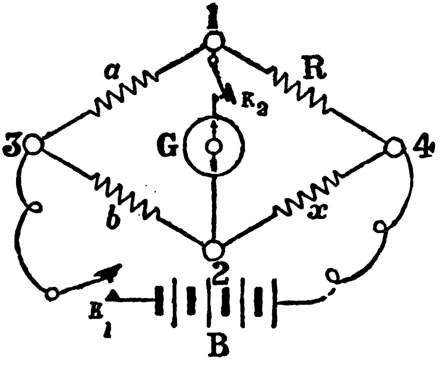


Fig. 1.*

Wheatstone's bridge or balance consists of four separate resistances, *a*, *b*, R, and *x*, arranged as shown in the theoretical diagram (fig. 1), with battery B, galvanometer G, and keys K_1, K_2.

x = the unknown or the resistance to be measured.

a and b two fixed resistances.

R = a variable resistance which is adjusted until, when K_1 and K_2 are depressed, no deflection is observed on galvanometer (G).

---

* See footnote, page 11.

Then the following ratio exists—

$$a : b :: \mathrm{R} : x,$$

$$\text{or } a\,x = b\,\mathrm{R},$$

or the products of the opposite sides of the bridge are always equal to each other,

$$\therefore x = \frac{b\,\mathrm{R}}{a}.\text{*}$$

Should the resistances a and b be equal, the value of x is read at once from R; should they, however, bear a certain ratio to each other, such as 1 to 10, 1 to 100, &c., or 10 to 1, 100 to 1, &c., (R) must be multiplied or divided by that ratio.

When further accuracy is desired than can be obtained by the ratios of a to b at disposal, note the galvanometer deflections to left and right, with the lesser and greater resistances in (R) respectively, and calculate by porportion the excess of the true resistance over lesser.

For example, let $a = 10$ and $b = 1000$, and let the true resistance of (x) lie between 5·11 and 5·12. If with $\mathrm{R} = 511$ we get 6 divisions to left $= (d_1)$, and with $\mathrm{R} = 512$ we get 12 to right $= (d_2)$.

Then $\qquad (d_1 + d_2) : 1 :: d_1 : y,$

i.e. $\qquad (6 + 12) : 1 :: 6 : y = \cdot\dot{3}.$

$$\therefore x = 5{\cdot}11\dot{3}$$

This method is very often used in practice with $a = b$ instead of using $\frac{a}{b} = \frac{1}{10}$ or $\frac{1}{100}$.

When taking the copper resistance of a submerged cable; if earth currents are present *always balance to cable or earth current zero.*

b. PRACTICAL FORMS OF WHEATSTONE BRIDGE.

1. Slide Wire or Metre Bridge.

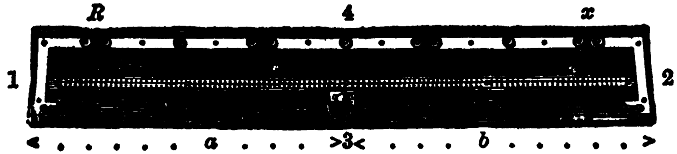


Fig. 2.

---

* For an investigation of the best conditions for making a test, see Kempe on "Electrical Testing," chap. vii., p. 119–132; Heaviside, *Phil. Mag.*, vol. xlv. 1873, p. 114; Gray, *Phil. Mag.*, Oct. 1881; Chrystal, "Electricity," *Encyclopædia Britannica.*

SLIDE WIRE OR METER BRIDGE, PLAN OF CONNECTIONS.

For measuring the resistance of short lengths of wire.

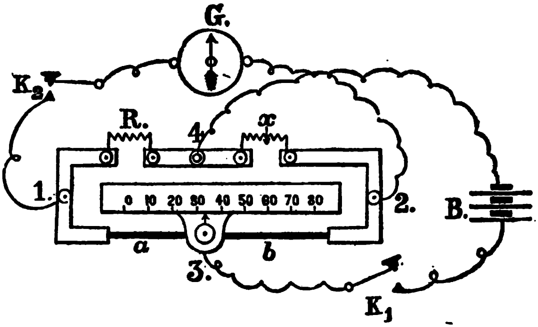


Fig. 3.*

Although great accuracy is not obtainable by this kind of bridge, as its working depends upon the assumption that the wire *a.b* is of uniform resistance throughout, it is nevertheless a very useful form of bridge for the workshop, and is generally used in connection with a horizontal needle or tangent galvanometer (G), and Daniell's or De la Rue's chloride of silver battery (B).

2. POST OFFICE PATTERN OF WHEATSTONE BRIDGE AND RESISTANCE BOX.

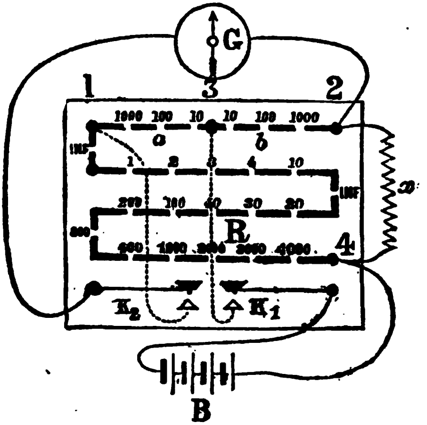


Fig. 4.*

---

* See footnote, page 11.

3. DIAL PATTERN OF WHEATSTONE BRIDGE AND RESISTANCE BOX.

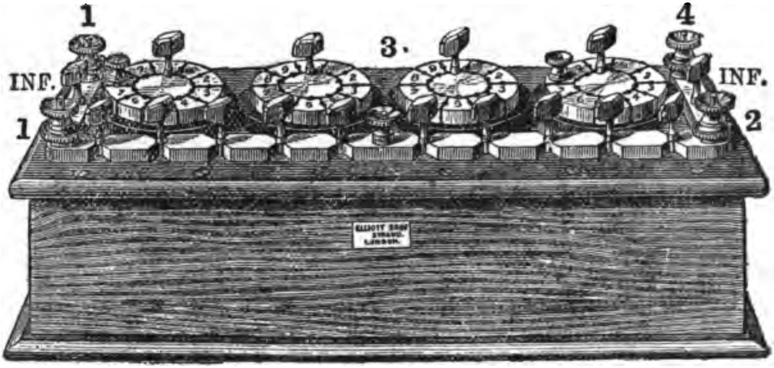


Fig. 5.

Plan of above.

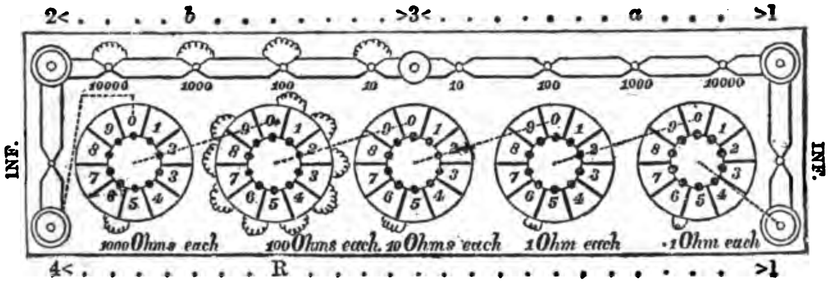


Fig. 6.

In this form of bridge and resistance box, the resistances are brought into circuit by the introduction of the plugs into the holes, which is the opposite of that in the Post Office pattern. It is therefore easier to read off from. The infinite resistance plug (INF.) between 2 and 4, or 1 and 1, must be removed when taking resistance by Bridge method.

NOTE.—All letters and numbers in Figs. 2, 3, 4, 5, 6, 7, 8, and 9, are the same as in theoretical diagram of Wheatstone Bridge, Fig. 1.

4. SIR WILLIAM THOMSON AND MR. VARLEY'S SLIDE RESISTANCE COILS.

General View.

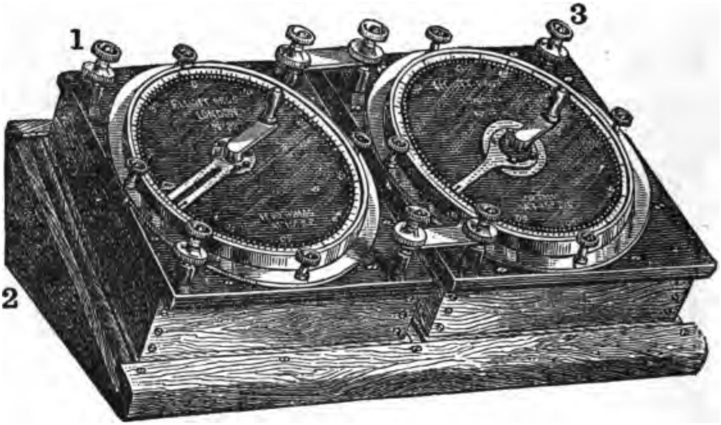


Fig. 7.

Plan with internal and external connections, joined up as an ordinary bridge. Same letters and figures as in Fig. 1.

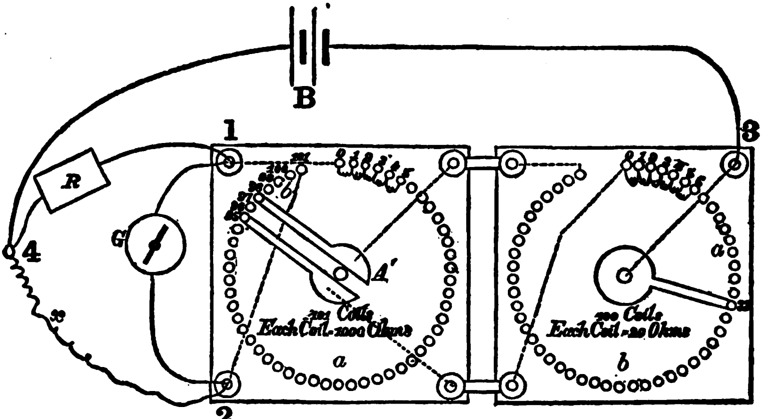


Fig. 8.

The above fig. (7) gives a general view of the slides, fig. 8 a plan with connections for testing the resistance of wires or

---

* See footnote, page 11.

cables on closed circuit, and fig. 9 a geometrical plan of the fall of potential in the slides, with the connections used in testing submarine cables, either for copper resistance or insulation during or after submersion.

The slides replace two arms of the Wheatstone bridge (a and b, see fig. 1), and the ratio $\frac{a}{b}$ is varied, not by inserting or taking out plugs, but by simply turning one or both of the handles.

In the left-hand box (figs. 7 and 8) we have the slides proper, consisting of 101 coils of 1,000 ohms each, or a total of 101,000 ohms, and in the right-hand box we have the vernier or subdividing slide, consisting of 100 coils of 20 ohms each, or a total of 2000 ohms. The double contact pointer, which is free to be moved from end to end of slide (*i.e.*, from 0 to 99 on one pointer and 2 to 101 on the other, or over 99 coils of 1000 ohms each, *i.e.*, over a total of 99,000 ohms on either pointer), embraces two coils (2000 ohms), but being attached to ends 0 and 100 of the vernier slide, it thereby introduces an equal resistance (2000 ohms), thus making the absolute resistance between the pointers equal to 1000 ohms, or the total resistance between the points 1 and 2 (figs. 8 and 9) of 100,000 ohms; for let

G = resistance between pointers $A' = 2000$ ohms,

S = resistance between 0 and 100, or vernier slide = 2000 ohms;

then, by shunt formula the joint resistance between two contact pointers, $A^1 = \frac{G\,S}{G+S} = \frac{2000 \times 2000}{2000+2000} = 1000$ ohms.

Part of the current from battery (fig. 9) therefore flows on short circuit through this 100,000 ohms resistance, and the remaining part through the resistance R and cable (x).

5., How to take a Test with Slides.

In taking a test of a cable, either for copper resistance or insulation, all that has to be done is to introduce a suitable resistance R, and move the slide handles until no deflection is observed on the galvanometer (when earth-currents are present balance to earth current zero). Then read the number on side of slides from zero marked a (fig. 9), and work out the following equation.

If R = resistance introduced in position R.

a = reading on slides, *i.e.*, from O to first pointer on left-hand or double pointer slide, plus O to single pointer on right-hand slide; see example, p. 15.

$b = 10{,}000 - a$.

x = resistance of cable to be found.

6. GEOMETRICAL PLAN OF SLIDE RESISTANCE COILS, WITH CONNECTION FOR COPPER RESISTANCE AND INSULATION.*

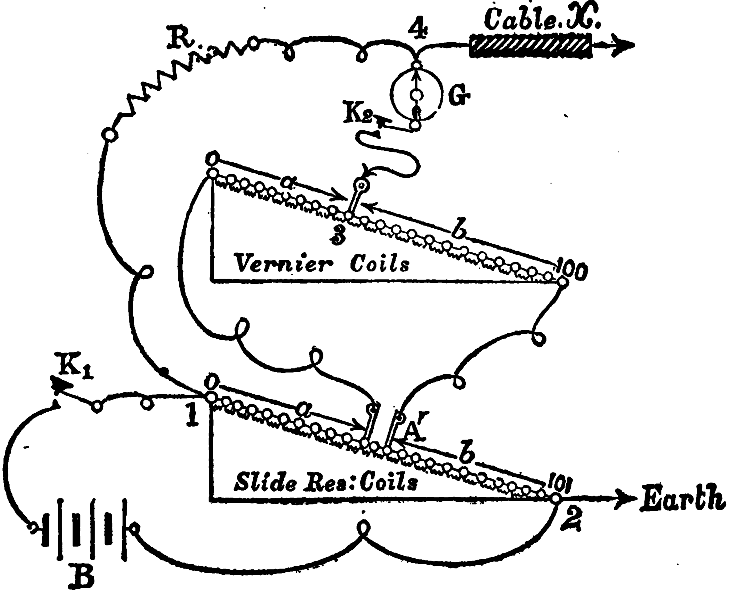


Fig. 9.

Note.—The same letters and numbers are used for fig. 9 as in fig. 1, but the position of Galvanometer and Battery are interchanged.

Then by rule for Wheatstone bridge, viz.—the product of the opposite sides of the bridge are equal (see p. 8 and fig. 1), we get

$$a : b :: \mathrm{R} : x,$$
$$i.e.,\ a : (10{,}000 - a) :: \mathrm{R} : x,$$
$$i.e.,\ ax = (10{,}000 - a)\ \mathrm{R},$$
$$x = \left(\frac{10{,}000 - a}{a}\right)\mathrm{R} = \left(\frac{10{,}000}{a} - 1\right)\mathrm{R}.$$

We have therefore only to look up for the reciprocal of the reading (a) in Barlow's or other tables (for reciprocals 1 to 1000 see pp. 1 to 30), multiply it by 10,000, subtract 1 and multiply by R to get x. For copper resistance tests R may conveniently be taken as the nearest multiple of 10 to the resistance of the cable or wire under test, and for insulation 1 megohm answers very well.

These slides are now very much used on cable expeditions, both during and after submersion.

---

* For Insulation test *Free Cable.* For Copper Resistance test *Earth Cable.*

Example.—The reading (a) on the slides (fig. 8) is 9532,

$$\therefore b = (10{,}000 - a) = (10{,}000 - 9532) = 468.$$

If R = 1000 ohms, then by formulæ

$$x = \left(\frac{10{,}000}{a} - 1\right)\mathrm{R} = \left(\frac{10{,}000}{9532} - 1\right)1{,}000 = 49{\cdot}09 \text{ ohms.}$$

For the reciprocal of 9532 $\left(\text{or } \frac{1}{9532}\right)$ (see tables, p. 29) = ·000104909,

$\therefore$ ·000104909 × 10,000 = 1·04909; (1·04909 − 1) 1000 = 49·09.*

b. TO MEASURE INSULATION OF CORE OR CABLE BY DIRECT DEFLECTION.

With Sir William Thomson's Mirror Galvanometer.

If l = length of cable in knots.
R = constant resistance in megohms.
G = galvanometer resistance in ohms.
s = resistance of shunt in ohms. used with res. R.
d_1 = deflection with full battery through res. R.
$\left(\frac{G+s}{s}\right)$ = multiplying power of shunt.
d_2 = deflection with cable using no shunt.

The constant of the galvanometer (unshunted) = $\mathrm{R}.d_1 \left(\frac{G+s}{s}\right)$

Absolute insulation of cable in megohms = x,

$$= \frac{\text{constant}}{d_2} = \left(\frac{\mathrm{R}\, d_1 \left(\frac{G+s}{s}\right)}{d_2}\right)$$

For Insulation per knot multiply absolute resistance by length in knots.†

c. MEASUREMENT OF ELECTRO-STATIC CAPACITY.

Sir William Thomson's Method.

This method is now almost universally adopted in comparing the capacity of condensers, or cables with condensers, both in the factory and at cable stations.

---

* The tests and calculations for resistances by slides are thus very easily, accurately, and quickly made.

† See Tables IX., X., and XI., for tests of recently submerged cable.

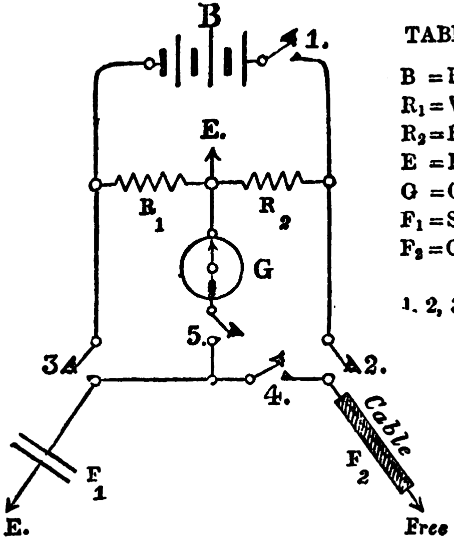


TABLE OF DETAILS.

B = Battery
R_1 = Variable Resistance.
R_2 = Fixed ,,
E = Earth.
G = Galvanometer.
F_1 = Standard Condenser.
F_2 = Cable or Condenser to be measured.
1, 2, 3, 4, 5 = Keys.

Fig. 10.

EXPLANATION OF FIGURE AND TEST.

1. Close key 1, then the poles of a well insulated battery (B), of from 1 to 10 Daniell or chloride of silver cells, are joined together through two resistances, R_1 and R_2, to earth.

Then, if V_1 and V_2 = the potentials at the points of junction of the battery with the resistances R_1 and R_2, we have

$$V_1 : V_2 :: R_1 : R_2.^*$$

2. By closing keys 2 and 3 simultaneously for a fixed time, the condenser and cable are charged to potentials V_1 and V_2 respectively.

If F_1 and F_2 be the respective capacities (in microfarads) of the condenser and cable, and Q_1 and Q_2 the charges given to them.

$$Q_1 : Q_2 :: V_1 F_1 : V_2 F_2.$$

3. Upon releasing keys 2 and 3, close key 4 for a fixed time, so as to allow the charges given to condenser and cable to *mix*,

---

* R_2 being a fixed resistance, and R_1 varied by trial, until no deflection is got through galvanometer.

then if $Q_1 = Q_2$, upon bringing the galvanometer into circuit by closing key 5, there will be no deflection.

$$\text{And } V_1 F_1 = V_2 F_2,$$
$$\text{or } V_2 : V_1 :: F_1 : F_2;$$

but from (1) we have

$$V_2 : V_1 :: R_2 : R_1,$$
$$\therefore R_2 : R_1 :: F_1 : F_2,$$

i.e., (capacity of cable) $F_2 = \frac{R_1}{R_2} F_1$ (microfarads).*

Mr. Lambert has lately designed a special key for taking this test. It does away with the necessity for using the four separate keys 2, 3, 4 and 5, and ensures greater certainty. It will at once be understood from the diagram.

LAMBERT'S KEY FOR THOMSON'S CAPACITY TEST.

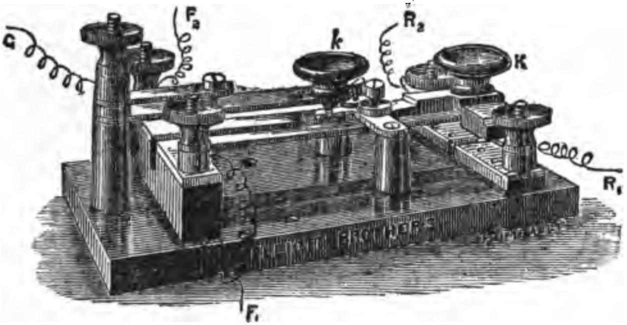


Fig. 11.

The letters at the ends of the leading wires in Fig. 11 indicate the parts in Fig. 10 to which they have to be attached.

By pushing forward key button K the two Condensers (or Condenser and Cable), F_1 and F_2, are simultaneously charged, and upon drawing it back their charges are allowed to mix; then by depressing key K, the galvanometer is brought into circuit.

In testing short lengths of core, say one-knot pieces, in the guttapercha factory, it saves calculation; if $R_2 = 5000$ ohms and $F_1 = \cdot 5$ microfarad, then the capacity can be read off directly to four places of decimals from R_1. If testing three to four knot-lengths, R_2 may conveniently be made equal to 1000 ohms, and $F_1 = 1$ microfarad.

When testing long submerged cables of, say, 1000 knots or more, R_2 may be $= 1000$ ohms, and $F_1 = 100$ microfarads. F_1 being composed of the large signalling condensers used at cable stations with siphon recorder or mirror. F_1 is first carefully tested and adjusted by comparing it with a standard condenser. If earth-currents exist, free cable by a special key immediately before discharging condenser (F_1) through galvanometer, taking the mean of several + and − readings.

---

* See example, page 18.

In order to get uniform capacity tests by this method, it is well to adopt some fixed time of charging and mixing, because condensers of different materials, such as a standard shellac mica condenser with a condenser of paraffined tinfoil, or a condenser and a cable, have different rates of absorption.

Dr Muirhead recommends, when comparing small capacities, say a standard $\frac{1}{3}$ to 1 microfarad shellac-mica condenser with a 10 to 20 microfarads paraffin-tinfoil one, a charge of 15 seconds, and a mix of 4 seconds. With a long cable of 1000 knots the author has found a charge of 5 minutes, with 10 seconds for mixing, to do very well.

Example.—Gibraltar-Malta Cable, tested at Malta by A. Jamieson. Length = 1120 knots; Insulation Resistance, 5th minute = 1490 megohms per knot; Total Copper Resistance = 11,293 ohms., or per knot = 10·083. F_1 = 100 microfarads of signalling condensers, carefully tested in portions of about 20 mfds., and then finally adjusted to a total of 100 mfds. by comparing with a 1 mfd. standard condenser; F_2 = total capacity of cable to be found; R_2 = 1000 ohms fixed resistance; R_1 = 3846 ohms (being a mean of 5 alternate tests with 10 cells, copper (+) and zinc (−) to cable), in order to eliminate the error arising from earth or cable currents. A very sensitive astatic minor galvanometer was used. The cable and the 100 mfds. condenser were charged simultaneously for 5 minutes, then allowed to *mix* for 10 seconds, both being earthed for a few minutes between each (+) and (−) test, in order to discharge them.

$$\text{By formula } F_2 = \frac{R_1}{R_2} F_1 = \frac{3846}{1000} 100 = 384{\cdot}6 \text{ microfarads.}$$

$$\therefore \text{ Capacity per knot} = \frac{\text{Total Capacity}}{\text{Length in Knots}} = \frac{384{\cdot}6}{1120} = 0{\cdot}3434 \text{ microfarad.}$$

A similar test from Gibraltar end gave 0·343 microfarad per knot.

d. MEASUREMENT OF POTENTIALS.*

ELECTRO-MOTIVE FORCES. LAWS'S METHOD.

The electro-motive force of a battery is the difference of the potentials at its poles when those poles are free.

1. Join up standard battery with discharge key and condenser ($\frac{1}{3}$ to 1 microfarad), charge condenser by depressing key, and discharge it through galvanometer by releasing key, note deflection and resistance of shunt s_1 used with the galvanometer of resistance, G.

---

* For other methods, see "Electrical Testing," Kempe, chap. xi.; "Electrical Tables," Clark and Sabine, pp. 90-94.

2. Introduce the battery whose E. M. F. is desired in place of standard battery, and effect the same operation, adjusting the shunt to s_2 until the same deflection is obtained as in former case.

Then, if E_1 and E_2 be the electro-motive forces of the batteries in volts

$$E_1 : E_2 :: \frac{G+s_1}{s_1} : \frac{G+s_2}{s_2}$$

If we obtain a suitable deflection, using no shunt with standard battery, then obtaining the same deflection with other battery,

$$E_2 = E_1 \frac{G+s_2}{s_2} \text{ (volts).}$$

Or, the unknown electro-motive force equals the known into the multiplying power of the shunt used.

N.B.—When comparing large with small electro-motive forces charge condenser with small battery first.

3. **By Slides.**—See fig. 9.—Leaving out the resistance R and cable x with their leads, place a standard battery of known E.M.F. with a single contact key between galvanometer (at 4) and earth. Let the current from larger battery, whose E.M.F. is required, flow directly through the slide res. coils from 1 to 2,—similar poles of each battery being next slides. Then, depressing the short circuit key for an instant at a time, move contact pointers to right or left, until no deflection is obtained on galvanometer; then the potential on each side of galvanometer must be equal.

Therefore, $E_2 = \frac{10{,}000}{a} E_1$ (volts), a being the reading on slides.

One of the ends of both batteries and end of coil 101 of slide res. coils are joined together.

c. BATTERY RESISTANCE. MUNRO'S METHOD.

This is practically the best test for battery resistance.

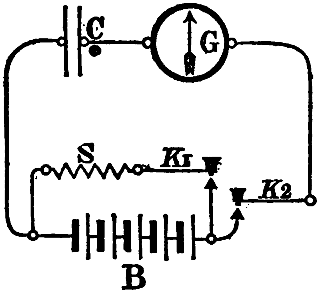


Fig. 12.

B = battery whose resistance is to be found.

C = small $\frac{1}{3}$ to 1 microfarad condenser.

S = shunt wire in ohms.

G = galvanometer.

K_1, K_2 = keys.

Plan of taking test—

Depress K_2 and note deflection d_2; still keeping K_2 down depress K_1, and note deflection d_1 (in reverse direction).

Then, r, battery resistance, $= S\frac{d_1}{d_2 - d_1}$.

f. JOINT TESTS.*

In the factory new joints, when cool, are tested against double their length of good core of the same size and material.

1. The joint is placed in a *thoroughly well insulated trough*, containing salt water and copper plate with an insulated lead attached to a condenser. The joint is then charged with 500 Daniell cells, further end being free, and the leakage through the joint to the plate and condenser noted after a half minute charge, by the discharge deflection on a sensitive Thomson's astatic mirror galvanometer.

2. Five to six feet of good core are treated in the same way, and if the joint is not worse than the core it is passed.

Joints on board ship during an expedition are seldom or ever tested, but they are made by thoroughly experienced and reliable workmen.

g. FAULTS IN SUBMERGED CABLES.†

Protection of Conductor.—Whenever a fault appears in a cable, which does not entirely prevent telegraphic communication, the signalling batteries at each end should be reduced in power to a minimum, and a small "protecting battery" attached to the end of cable nearest fault as a T piece, with its (–) pole fixed to the junction between cable and signalling condensers, and its (+) pole to earth through a high resistance (say 10,000 ohms). This causes a negative current to flow constantly to the fault, which keeps it clean, and prevents the conductor being eaten away at the fault by the signalling currents.

Localising Faults.—The "breaking down" of a high resistance, or small fault, with strong reversing currents should only be resorted to after every other method of localising it has failed, as such treatment has a great tendency to produce other faults, especially if the original fault be at a considerable distance. In all cases, when localising faults, use as small a battery power as practicable, just sufficient to enable the resistance to or of the fault to be determined with accuracy. Never depend entirely upon results obtained with the (+) pole of the battery to cable, or with observations taken after the resistance of the fault has begun to increase with the (–) pole to cable, since a (+) current has the power of depositing copper salts at, and thereby increasing the resistance of, the fault, while the (–) current reduces and throws off these salts, but immediately thereafter it begins to generate hydrogen, which also clings to, polarises, and increases the resistance of the fault. It is therefore best in all cases where the fault makes earth, to charge first with a (+) current, and then to take observations with a (–) current, noting, as most correct, that obtained immediately before a sudden increase in resistance takes place. The testing battery should be very constant, well insulated, and of low resistance, such as De la Rue's chloride of silver cells, or good Daniell's, with large well amalgamated zinc plates.

In all cases, such as Varley's Loop and Blavier's, where it is advisable to balance to earth or cable current zero, a sensitive *dead beat* mirror galvanometer is preferable to an equally, or even more sensitive astatic galvanometer.

In all cases where the resistance of a fault bears an appreciable ratio to the *absolute* insulation of the cable, it is advisable to make correction for the apparent position of the same by taking into account the position and resistance of the "natural resultant fault." In single cables this "natural resultant fault" has generally to be assumed to be at the centre of the cable, and is equal to the absolute insulation (see "Electrical Tables," Clark & Sabine, p. 45); but in duplicate cables, or where a loop test can be applied, the exact position and value of the natural resultant fault should be frequently obtained by a Varley's Loop and ordinary insulation tests. In dealing with long cables and faults of, say, over 100 ohms resistance, this correction is absolutely necessary before the true position of the fault can be arrived at with accuracy.

---

* See "Electrical Testing," Kempe, chap. xviii.

† For tests of Faults in cables, land lines, and short lengths of core, see "Electrical Tables," Clark and Sabine, pp. 41–60; "Electrical Testing," Kempe, chaps. ix. and xvi.; "Electricity and Magnetism," Jenkin, chap. xxv.

§ IV.—*a*. COPPER.

1. The **specific gravity** of copper wire used for conductors is about = 8·899.

2. One cubic foot weighs about 550 lbs., therefore one cubic inch = 0·32 lbs.

3. The **melting point** of copper is about 2000° Fah.

4. The **strength** of a wire or strand is $1\frac{1}{2}$ lbs. per pound weight per knot—*i.e.*, a strand weighing 200 lbs. per knot would bear 300 lbs., and stretch from 10 to 15 per cent. before breaking.

5. The weight per knot of a copper wire is about $\frac{d^2}{55}$ lbs.: d being the diameter in mils., and for a strand $\frac{d^2}{70\cdot4}$ mils.*

6. The diameter of a copper wire weighing (w) lbs. per knot, is about $7\cdot4\sqrt{w}$ mils., and for a strand about $8\cdot4\sqrt{w}$ mils.*

7. The resistance of a knot of pure copper wire weighing 1 lb. is 1192·45 ohms at 75° Fah.*

8. The resistance per knot of any pure copper wire, d mils. in diameter, is $\frac{65306}{d^2}$ ohms at 75° Fah.

The resistance per statute mile (1760 yards) of any pure copper wire, (d) mils in diameter, is $\frac{54892}{d^2}$ ohms at 60° Fah.

From which we get the *resistances of copper wire per* 100 yards at 60° Fah.

d = (diameter in inches).

$$\text{Pure} = \frac{\cdot003118}{d^2};\quad 98 \text{ per cent. } \frac{\cdot003185}{d^2};$$

$$96 \text{ per cent.} = \frac{\cdot003265}{d^2};\quad 94 \text{ per cent. } \frac{\cdot003335}{d^2};$$

$$92 \text{ per cent.} = \frac{\cdot003400}{d^2};\quad 90 \text{ per cent. } \frac{\cdot003478}{d^2}$$

9. **The resistance per knot** of a cable conductor is equal to 120,000 divided by the product of the percentage conductivity of the copper and its weight per knot in lbs.

10. The **Specific Conductivity** of pure copper is taken as 100. The copper used for telegraphic and electric lighting conductors is of lower conductivity, or, in other words, of higher resistance, but ought never to be under 90 per cent. of that of pure copper.

---

* The weight and resistance of a copper strand are best found by multiplying the above results for one wire, by the number of wires composing the strand. A mil. = $\frac{1}{1000}$ of an inch, or ·001 inch.

It can be obtained equal to 98, and many firms will guarantee 95 per cent.

11. The **Percentage Conductivity** of any copper wire is found by multiplying the resistance of a pure copper wire of the same gauge and length by 100, and dividing the product by the actual resistance of the former at the same temperature.

12. A wire of pure annealed copper, 100 inches in length, weighing 100 grains, has a resistance of 0·1516 ohms at 60° Fah.; therefore the conductivity of any other wire, (l) inches in length, weighing (w) grains, and having a resistance (r) ohms, is

$$=\frac{0{\cdot}1516\times l^2}{w\,r}\text{ (at 60° Fah.)}$$

and the resistance $=\dfrac{\cdot001516\times l^2}{w}$ (ohms at 60° Fah.)*

13. The **Resistance of Copper** increases as the temperature rises, about 0·21 per cent. for each degree Fah., or about 0·38 per cent. for each degree Cent.

14. The **Standard Temperature** for copper resistance is 5° Fah. To calculate what will be the resistance at 75° *add* to the log. of the actual resistance the log. opposite the temperature in the following table, IV., and their sum = the log. of the res. at 75°. To use the table for temperatures above 75° take the same number of degrees below 75, and *subtract* the log. opposite from the log. of the actual res.

E.g., let the temperature $=82°$, then $82-75=7 \therefore 75-7=68$. Referring to table the log. opposite $68=\cdot00638$, which subtract from the log. of res. in order to get log. of res. at 75.

German Silver weighs about 530 lbs. per cubic foot, specific gravity 8·5.

A prism of German silver one metre long and one square millimetre in section, weighs about 8·5 grammes, and its resistance is about 0·206 ohm. at 0° C., and increases about ·04 per cent. per 1° C. The resistance of a prism of German silver one metre long, weighing one gramme, is about 1·75 ohms. at 0° C.

* Standard resistances = 0·1516 ohms at 60° Fah., and samples of pure copper wire of different gauges are obtainable for measuring the specific conductivity of conducting wires. All copper wire intended for telegraphic or electric lighting, or telephonic purposes, should be carefully tested before being accepted. A portion of the wire to be used may be drawn down to a fine size, and tested by the ordinary Wheatstone Bridge and resistance coils, care being taken to note temperatures of wire and bridge, as well as length and weight of former; or Elliot's or Hockin's meter bridges may be used for larger sizes of wire (see figs. 2 and 3).

TABLE III.—RESISTANCE AND WEIGHT.

COPPER WIRE.

(From "The Electrician.")

The resistances are calculated for pure copper wire.
The number of feet to the pound is only approximate for insulated wire.

Nearest B. W. G.	Diameter.	Feet per pound.			Resistance, naked Copper.			
		Cotton-covered.	Silk-covered.	Naked.	Ohms per 1000 feet.	Ohms per mile.	Feet per ohm.	Ohms per pound.
10½	·12849	...	...	20	·6259	3·3	1600·	·0125
11½	·11443	...	...	25	·7892	4·1	1272·	·0197
12½	·10189	...	...	32	·8441	4·4	1185·	·0270
13½	·09074	...	...	40	1·254	6·4	798·	·0501
14	·08081	42	46	50	1·580	8·3	633·	·079
15	·07196	55	60	64	1·995	10·4	504·	·127
16	·06408	68	75	80	2·504	13·2	400·	·200
17	·05707	87	96	101	3·172	16·7	316·	·320
18	·05082	110	120	128	4·001	23·	230·	·512
18½	·04525	140	150	161	5·04	26·	193·	·811
19	·0403	175	190	203	6·36	33·	157·	1·29
20	·03539	220	240	256	8·25	43·	121·	2·11
21	·03196	280	305	324	10·12	53·	99·	3·27
22	·02846	360	390	408	12·76	68·	76·5	5·20
23	·02535	450	490	514	16·25	85·	61·8	8·35
24	·02257	560	615	649	20·30	108·	48·9	13·3
25	·0201	715	775	818	25·60	135·	39·0	20·9
26	·0179	910	990	1030	32·2	170·	31·0	33·2
27	·01594	1165	1265	1300	40·7	214·	24·6	52·9
28	·01419	1445	1570	1640	51·3	270·	19·5	84·2
29	·01264	1810	1970	2070	64·8	343·	15·4	134·
30	·01126	2280	2480	2617	81·6	432·	12·2	213·
31	·01002	2805	3050	3287	103·	538·	9·8	338·
32	·00893	3605	3920	4144	130·	685·	7·7	539·
33	·00795	4535	4930	5227	164·	865·	6·1	856·
34	·00708	...	6200	6590	206·	1033·	4·9	1357·
...	·0063	...	7830	8330	260·	1389·	3·8	2166·
...	·00561	...	9830	10460	328·	1820·	2·9	3521·
35	·005	...	12420	13210	414·	2200·	2·4	5469·

in a
an
gen
pot
to l
nec

eit

ac

su
fe

t
a

AND FORRULE.

CALCULATING COPPER

By CLARK,

	3	·4
[illegible]	[illegible]	0·03881
[illegible]	[illegible]	·03790
[illegible]	[illegible]	·03699
[illegible]	[illegible]	·03605
[illegible]	[illegible]	·03517
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

TABLE IV.

RESISTANCE AT DIFFERENT TEMPERATURES FAH.*

Forde & Co.

·5	·6	·7	·8	·9	Deg.
0·03872	0·03863	0·03854	0·03845	0·03836	32
·03781	·03772	·03763	·03754	·03745	33
·03690	·03681	·03672	·03663	·03654	34
·03599	·03590	·03581	·03572	·03562	35
·03508	·03499	·03490	·03480	·03471	36
·03417	·03408	·03398	·03389	·03380	37
·03326	·03316	·03307	·03298	·03289	38
·03234	·03225	·03216	·03207	·03198	39
·03143	·03134	·03125	·03116	·03107	40
·03052	·03043	·03034	·03025	·03016	41
·02961	·02952	·02943	·02934	·02925	42
·02870	·02861	·02852	·02843	·02834	43
·02779	·02770	·02761	·02752	·02742	44
·02688	·02679	·02670	·02660	·02651	45
·02597	·02588	·02578	·02569	·02560	46
·02506	·02496	·02487	·02478	·02469	47
·02414	·02405	·02396	·02387	·02378	48
·02323	·02314	·02305	·02296	·02287	49
·02232	·02223	·02214	·02205	·02196	50
·02141	·02132	·02123	·02114	·02105	51
·02050	·02041	·02032	·02023	·02014	52
·01959	·01950	·01941	·01932	·01922	53
·01868	·01859	·01850	·01840	·01831	54
·01777	·01768	·01758	·01749	·01740	55
·01686	·01676	·01667	·01658	·01649	56
·01594	·01585	·01576	·01567	·01558	57
·01503	·01494	·01485	·01476	·01467	58
·01412	·01403	·01394	·01385	·01376	59
·01321	·01312	·01303	·01294	·01285	60
·01230	·01221	·01212	·01203	·01194	61
·01139	·01130	·01121	·01112	·01102	62
·01048	·01039	·01030	·01020	·01011	63
·00957	·00948	·00938	·00929	·00920	64
·00866	·00856	·00847	·00838	·00829	65
·00774	·00765	·00756	·00747	·00738	66
·00683	·00674	·00665	·00656	·00647	67
·00592	·00583	·00574	·00565	·00556	68
·00501	·00492	·00483	·00474	·00465	69
·00410	·00401	·00392	·00383	·00374	70
·00319	·00310	·00301	·00292	·00282	71
·00228	·00219	·00210	·00200	·00191	72
·00137	·00128	·00118	·00109	·00100	73
·00046	·00036	·00027	·00018	·00009	74

to use Tables, see p. 22.—14.

TABLE V

TABLE OF DIAMETERS, LENGTHS PER POUND, AND RESISTANCES OF PURE COPPER AND GERMAN SILVER WIRES (AT 60° FAH.)

(*Hall, Wire Manufacturer, &c.*)

Birmingham Wire Gauge (Approximate.) (see Table XVIII.)	Diameter.		Number of yards in 1 pound.	Weight in lbs. of 1 mile (1760 yards).	Resistance of 1 mile of pure Copper at 32° Fah.	Resistance of 36 inches of German Silver Wire at 60° Fah. by Elliot Brothers.
	Inches.	Milli-metres.				
4¼	·2302	5·847	2·095	840·09	1·00	·00846
5	·226	5·740	2·175	809·20	1·038	·0088
6¼	·198	5·029	2·834	621·00	1·352	·01144
7	·183	4·648	3·317	530·59	1·583	·0134
7½	·175	4·445	3·628	485·10	1·731	·0146
8¼	·160	4·064	3·350	404·60	2·068	·017$_{5}$2
10	·136	3·454	6·007	292·99	2·867	·02425
10½	·128	3·251	6·781	259·55	3·237	·0273
12	·107	2·717	9·705	181·35	4·623	·0393
12½	·10	2·54	11·11	158·41	5·300	·045
13	·092	2·336	13·125	134·40	6·266	·053
14¼	·08	2·032	17·36	101·39	8·288	·07
15	·07	1·778	22·67	77·63	10·82	·091
16	·065	1·651	26·29	66·96	12·25	·104
16½	·0625	1·587	28·472	61·81	13·59	·115
...	·06	1·521	30·864	57·02	14·73	·125
17	·058	1·473	33·03	53·29	15·76	·134
...	·056	1·422	35·432	49·67	16·91	·144
...	·054	1·371	38·104	46·19	18·18	·154
...	·052	1·32	41·091	42·83	19·61	·166
18	·05	1·274	44·444	39·60	21·21	·180
...	·048	1·219	48·225	36·50	23·02	·195
18½	·046	1·168	52·51	33·52	25·06	·213
...	·044	1·117	57·39	30·67	27·39	·232
19	·042	1·066	62·98	27·94	30·06	·255
...	·04	1·016	69·444	25·34	33·14	·281
...	·038	·965	77·16	22·81	36·72	·312
20	·036	·914	85·766	20·52	40·92	·348
	·034	·864	95·29	18·47	45·48	·386

TABLE V.—*continued.*

Birmingham Wire Gauge (Approximate.) (see Table XVIII.)	Diameter.		Number of yards in 1 pound.	Weight in lbs. of 1 mile (1760 yards.)	Resistance of 1 mile of pure Copper at 32° Fah.	Resistances of 36 inches of German Silver wire at 60° Fah. by Elliot Brothers.
	Inches.	Milli-metres.				
21	·032	·813	108·5	16·22	51·79	·44
21½	·03	·762	123·46	14·26	58·93	·5
22	·028	·711	141·72	12·42	67·65	·574
23½	·026	·660	164·36	10·71	78·46	·666
...	·024	·609	192·9	9·12	92·08	·782
24	·022	·558	229·56	7·61	109·58	·931
25	·02	·508	277·78	6·33	132·59	1·12
26	·018	·457	342·94	5·13	163·69	1·39
27	·016	·406	434·03	4·05	207·17	1·76
28	·014	·355	569·51	3·09	270·58	2·3
30	·012	·305	771·60	2·28	368·30	3·23
31	·01	·254	1111·11	1·58	530·35	4·6
31½	·0095	·241	1231·10	1·43	587·64	4·994
32	·009	·228	1371·7	1·28	654·75	5·565
32½	·0085	·216	1537·8	1·14	734·05	6·239
33	·008	·203	1736·1	1·01	828·67	7·04
33½	·0075	·190	1975·3	0·8910	942·84	8·014
34	·007	·177	2267·6	0·7761	1082·4	9·2
34½	·0065	·165	2629·9	0·6692	1225·3	10·41
34½	·006	·152	3086·4	0·5702	1473·1	12·52
...	·0055	·139	3673·1	0·4791	1753·2	14·992
35	·005	·127	4444·4	0·3960	2121·4	18·032
35½	·0045	·114	5487·0	0·3207	2619·0	22·261
36	·004	·106	6944·4	0·2534	3314·7	28·175
...	·0035	·088	9070·3	0·1945	4329·4	36·9
...	·003	·076	12346·0	0·1425	5892·7	50·077
...	·0025	·063	17777·0	0·099	8435·6	72·127

To find the percentage of conductivity in a sample of wire, pure copper being taken as = 100.

Divide the resistance of 1 mile of pure copper wire of the same size (column 6), by the actual resistance of 1 mile of the wire tested (reduced to 32° Fah.), and multiply by 100. This table is used by Elliot Brothers.

(FROM "THE ELECTRICIAN.")

Value of Copper Conductor at £85 per ton.

Diam. in inches.	Sectional area.	Weight per mile.			Cost per mile at £85 per ton.			Resistance at 96°/o	B. W. G.
		Tons.	cwt.	lbs.	£	s.	d.	Ohms.	
1·00	·7854	7·109	...	...	604	0	0	·0575	...
·707	·3927	3·554	...	...	302	0	0	·1150	...
·500	·1963	1·787	...	...	151	0	0	·2300	...
·354	·0981	...	17·8	...	75	10	0	·4600	...
								at 98°/°	
·238	...	...	...	864	38	0	0	1·00	4
·220	...	...	...	775	34	0	0	1·16	5
·211	...	...	...	705	30	18	0	1·26	5½
·203	...	...	...	660	29	0	0	1·36	6
·191	...	...	...	580	25	9	0	1·54	6½
·180	...	...	...	515	22	10	0	1·73	7
·172	...	...	...	464	20	8	0	1·89	7½
·165	...	...	...	430	18	18	0	2·06	8

No. 8 is the most convenient for stretching easily and making a neat job.

§ V.—*a.* GUTTAPERCHA.

1. **The Specific Gravity** of guttapercha is between 0·9693 and 0·981.

2. One cubic foot weighs between 60·56 and 61·32 lbs.; therefore, one cubic inch weighs between 0·560 and 0·567 ounces.

3. **Guttapercha softens** at 115° Fah., becomes plastic at 120°, melts at 212°, and is fluid at about 266°. When exposed to the air, particularly at temperatures between 70 and 90° Fah., it oxidises, becomes brittle, shrinks, and cracks.

This is very noticeable in guttapercha leads, used at telegraph offices in tropical climates.

Exposure to light hastens oxidation.

Oxidation and decay are hindered by serving guttapercha core with tape soaked in Stockholm tar; but the natural acid of the tar *must first* be removed, otherwise the insulation will be reduced. Guttapercha leads encased in lead tubing remain perfect for years. No deterioration is observable in guttapercha if kept *continually* under water.

4. **Stretched Guttapercha,** as used for core, resists a strain of 1000 lbs. per square inch before permanent elongation takes

place, and breaks at about 3500 lbs. per square inch. Stretching increases the tenacity of guttapercha in the direction stretched.

5. **The weight** of guttapercha per knot in any core is $\frac{D^2 - d^2}{491}$, where D = diameter of guttapercha, and d = diameter of copper, (both in mils.)

6. **The exterior diameter** of any guttapercha core

$$= \sqrt{70{\cdot}4\, w + 491\, W} \text{ mils.},$$

where w is the weight in lbs. per knot of copper strand, and W that of the guttapercha. With a solid conductor the diameter

$$= \sqrt{55\, w + 491\, W} \text{ mils.}$$

7. **The electro-static capacity** per nautical mile of any guttapercha core is approximately

$$\frac{0{\cdot}1877}{\log D - \log d} \text{ microfarads.}$$

8. **The electro-static capacity** of guttapercha core, as compared with indiarubber core of similar size, is as 120 to 100 nearly.

9. **The Insulation-resistance** per knot of a guttapercha core of the best quality = 769 (Log D − log d) megohms at 75° Fah.

10. **The resistance** of guttapercha under pressure increases in the following ratio* :—

Let R be the resistance at atmospheric pressure, the resistance under the pressure p lbs. per square inch

$$= R\,(1 + 0{\cdot}00023\, p).$$

11. **The resistance** of guttapercha diminishes as the temperature increases; the rate of decrease is as follows* :—

Let R = resistance at the higher temperature;
r = resistance at the lower temperature;
t = the difference of temperature in degrees Fah.,—then

$$\log \text{ of } R = \log r - t \log 0{\cdot}9399,$$
$$\text{and } \log \text{ of } r = \log R + t \log 0{\cdot}9399.$$

Tables of resistance of guttapercha at different temperatures are given on the following page. (Table VI.)

---

* When a submarine cable is laid in deep water, the insulation is greatly improved owing to the pressure of the water and lower temperature (see Table XI.).

TABLE VI.—THE RELATIVE RESISTANCE (AFTER 1 MINUTE) OF ORDINARY GUTTAPERCHA AT DIFFERENT TEMPERATURES, FOR ALL CORES IN WHICH THE THICKNESS OF GUTTAPERCHA DOES NOT EXCEED 0·11 INCH.—(*W. Smith.*) *

Temperature.		Relative Resistance.†	Log Resistance.	Temperature.		Relative Resistance.†	Log Resistance.
Fah.	Cent.			Fah.	Cent.		
32	0·0	23·622	·373317	67	19·4	1·801	·255514
33	0·5	21·947	·341375	68	20·0	1·673	·223496
34	1·1	20·391	·309439	69	20·5	1·555	·191730
35	1·6	18·945	·277495	70	21·1	1·444	·159567
36	2·2	17·602	·245562	71	21·6	1·342	·127753
37	2·7	16·354	·213624	72	22·2	1·247	·095867
38	3·3	15·195	·181701	73	22·7	1·158	·063709
39	3·8	14·117	·149742	74	23·3	1·076	·031812
40	4·4	13·116	·117801	75	23·8	1·000	·000000
41	5·0	12·186	·085861	76	24·4	·9418	·973959
42	5·5	11·322	·053923	77	25·0	·8870	·947924
43	6·1	10·52	·022016	78	25·5	·8354	·921895
44	6·6	9·774	·990072	79	26·1	·7867	·895809
45	7·2	9·081	·958134	80	26·6	·7410	·869818
46	7·7	8·437	·926188	81	27·2	·6978	·843731
47	8·3	7·839	·894261	82	27·7	·6572	·817698
48	8·8	7·283	·862310	83	28·3	·6190	·791691
49	9·4	6·767	·830396	84	28·8	·5829	·765594
50	10·0	6·287	·798444	85	29·4	·5490	·739572
51	10·5	5·841	·766487	86	30·0	·5171	·713575
52	11·1	5·427	·734560	87	30·5	·4870	·687529
53	11·6	5·042	·702603	88	31·1	·4586	·661434
54	12·2	4·685	·670710	89	31·6	·4319	·635383
55	12·7	4·353	·638789	90	32·2	·4068	·609381
56	13·3	4·044	·606811	91	32·7	·3831	·583312
57	13·8	3·757	·574841	92	33·3	·3608	·557267
58	14·4	3·491	·542950	93	33·8	·3398	·531223
59	15·0	3·244	·511081	94	34·4	·3200	·505150
60	15·5	3·013	·478999	95	35·0	·3014	·479143
61	16·1	2·800	·447158	96	35·5	·2839	·453165
62	16·6	2·601	·415140	97	36·1	·2674	·427161
63	17·2	2·417	·383277	98	36·6	·2518	·401056
64	17·7	2·245	·351216	99	37·2	·2371	·374932
65	18·3	2·086	·319314	100	37·7	·2238	·348889
66	18·8	1·938	·287354				

* From "Electrical Tables," Clark and Sabine.

The above table is for new core, as guttapercha improves greatly with age.

† For example :—The resistance at 32° Fah. is 23·622 times greater than at 75° Fah. Therefore, in order to reduce the observed resistance at any temperature to what it will be at 75° Fah., refer to the above table, and divide the observed resistance by the number in the relative resistance column, found opposite the temperature of the G.P. at time of test.—A. J.

12. A plate of guttapercha, 1 square foot surface and 1 mil. thick, has a *resistance* = 1066 megohms at 75° Fah.; and its electro-static capacity = ·1356 microfarads.

13. The insulation resistance, in megóhms, at 75° Fah., of an ordinary guttapercha cable or condenser, multiplied by its electro-static capacity, in microfarads = 144·4.

14. Ratio of $\frac{D}{d}$ for strand and solid conductors.

A solid wire, covered with guttapercha—

$$\frac{D}{d} = \sqrt{1 + 8{\cdot}93\,\frac{W}{w}}.$$

A strand, covered with guttapercha—

$$\frac{D}{d} = 1{\cdot}05\,\sqrt{1 + 6{\cdot}97\,\frac{W}{w}}$$

* Where D = diameter of core, and d = diameter of wire or mean diameter of strand, both in mils.; W = weight of guttapercha, and w = weight of conductor, both in lbs.

b. WILLOUGHBY SMITH'S IMPROVED GUTTAPERCHA.†

15. **The specific gravity** of guttapercha prepared by Mr. Willoughby Smith's process is the same as that of ordinary guttapercha.

16. **The mechanical strength** of this material is about 12 per cent. greater than that of ordinary guttapercha.

17. **The electro-static capacity** (F) per knot of a core of Smith's guttapercha is approximately

$$F = \frac{0{\cdot}15163}{\log \frac{D}{d}} \text{ microfarads.}$$

---

* For table to find resistance (after 1 minute) and capacity per knot of any ordinary guttapercha core from relative weights or diameter of $\left(\frac{\text{insulator}}{\text{conductor}}\right) \frac{D}{d}$,—see Clark and Sabine, "Electrical Tables," page 122

† Also page 124.

TABLE VII.

RELATIVE RESISTANCE (AFTER 1 MINUTE) OF WILLOUGHBY SMITH'S IMPROVED GUTTAPERCHA AT DIFFERENT TEMPERATURES, FOR ALL CORES IN WHICH THE THICKNESS OF GUTTAPERCHA DOES NOT EXCEED 0·110 INCH.—(*W. Smith.*)*

Temperature.		Relative Resistance.†	Log Resistance.	Temperature.		Relative Resistance.†	Log Resistance.
Fah.	Cent.			Fah.	Cent.		
32	0·0	27·913	·445807	67	19·4	1·858	·269046
33	0·5	25·834	·412192	68	20·0	1·719	·235276
34	1·1	23·91	·378580	69	20·5	1·591	·201670
35	1·6	22·128	·344942	70	21·1	1·473	·168203
36	2·2	20·48	·311330	71	21·6	1·363	·134496
37	2·7	18·954	·277701	72	22·2	1·261	·100715
38	3·3	17·542	·244079	73	22·7	1·167	·067071
39	3·8	16·235	·210452	74	23·3	1·080	·033424
40	4·4	15·025	·176815	75	23·8	1·000	·000000
41	5·0	13·906	·143202	76	24·4	·9375	·971971
42	5·5	12·87	·109579	77	25·0	·8789	·943940
43	6·1	11·911	·075948	78	25·5	·8240	·915927
44	6·6	11·024	·042339	79	26·1	·7725	·887899
45	7·2	10·203	·008728	80	26·6	·7242	·859859
46	7·7	9·442	·975064	81	27·2	·6789	·831806
47	8·3	8·739	·941462	82	27·7	·6365	·803798
48	8·8	8·088	·907841	83	28·3	·5967	·775756
49	9·4	7·485	·874192	84	28·8	·5594	·747723
50	10·0	6·928	·840608	85	29·4	·5245	·719746
51	10·5	6·412	·806994	86	30·0	·4917	·691700
52	11·1	5·934	·773348	87	30·5	·4609	·663607
53	11·6	5·492	·739731	88	31·1	·4321	·635584
54	12·2	5·083	·706120	89	31·6	·4051	·607562
55	12·7	4·704	·672467	90	32·2	·3798	·579555
56	13·3	4·354	·638888	91	32·7	·3561	·551572
57	13·8	4·029	·605197	92	33·3	·3338	·523486
58	14·4	3·729	·571592	93	33·8	·3130	·495544
59	15·0	3·451	·537945	94	34·4	·2934	·467460
60	15·5	3·194	·504335	95	35·0	·2751	·439491
61	16·1	2·956	·470704	96	35·5	·2579	·411451
62	16·6	2·736	·437116	97	36·1	·2417	·383277
63	17·2	2·532	·403464	98	36·6	·2266	·355260
64	17·7	2·343	·369772	99	37·2	·2125	·327359
65	18·3	2·169	·336260	100	37·7	·1992	·299289
66	18·8	2·007	·302547				

---

* From "Electrical Tables," Clark and Sabine.

† The above table is for new core, as this core, like ordinary guttapercha, improves greatly with age. See footnote, Table VI., p. 30, for plan of using the above table.—A. J.

18. **The Insulation-resistance** (R) per knot of Smith's gutta-percha core at 75° Fah. (= 24° Cent.) is approximately

$$R = 350 \log \frac{D}{d} \text{ megohms}$$[*]

after one minute's electrification.

19. **The resistance** after the first minute, of Smith's gutta-percha at 32° Fah., is about the same as that of ordinary gutta-percha. After a long application of the battery at this temperature the ratio falls to 72 : 100, about.

20. **The resistance** after the first minute, of Smith's gutta-percha at 75° Fah., compared with that of ordinary gutta-percha, is as 67 to 100, or about 30 per cent. inferior.

STANDARD TEMPERATURE FOR DIELECTRIC TESTS.

21. It is usual in specifications for good core to specify that the conductor and dielectric shall have a certain resistance at 75° Fah., and all tests taken at other temperatures are reduced by tables to that temperature for comparison. It is also usual to specify that the core shall be kept for 24 hours at a constant temperature of 75° Fah. before being tested and passed for sheathing; but it is evident that tests taken at this temperature are not nearly so searching for small faults (owing to the absolute resistance being low) as they would be if taken at a lower temperature, say from 40° to 50° Some well-known firms, therefore, make a point of taking final tests before passing core for sheathing at as low a temperature as practicable.

c. EBONITE.

Hard Good Quality.—	Best para rubber	2	parts by weight.
	Sulphur	1	,,
American Ebonite :—	Rubber	12	,,
	Sulphur	8	,,
	Whiting	1	,,
	Wash	1	,,
Curing moulds for above :—	Lead	2	,,
	Antimony	1	,,
Soft vulcanised india-rubber :—	Para rubber	7·5	,,
	Sulphur	·75	,,
	Lime	·01	,,
	Whiting	7·5	,,
	French chalk	1·25	,,
	Litharge	1·5	,,

[*] For table to find resistance (after 1 minute) and capacity per knot of Willoughby Smith's guttapercha core from the relative weights or diameters of $\left(\frac{\text{insulator}}{\text{conductor}}\right)\frac{D}{d}$,—see "Electrical Tables," Clark and Sabine, page 127.

§ VI.—BATTERIES

a. De la Rue's Chloride of Silver Battery.

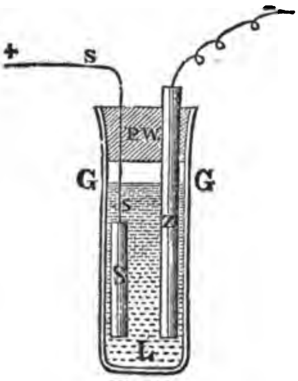


Fig. 13.

TABLE OF DETAILS.

G G = Glass vessel closed by
P W = Stopper of paraffin wax.
Z = Zinc or positive element, consisting of a cylindrical rod of chemically pure zinc.
S = Chloride of silver cylinder, or negative element, surrounded by parchment paper to prevent contact with Z.
s = Fine silver electrode cast into S.
L = Liquid solution of chloride of ammonium, (403) grains to 1 quart water

The chloride of silver, being insoluble, no porous diaphragm is required. The electro-motive force of this cell is 1·030 volts. The internal resistance of the cell is 3 to 4 ohms. Mr. De la Rue has found that the internal resistance increases to 18 ohms after standing eighteen months, this increase being due to the gradual formation and adherence round the zinc of oxychloride of zinc, but that the cell can be restored immediately to its normal state by scraping the zinc rod. The resistance does not increase by considerable use, which tends to keep the zinc clean. Mr. De la Rue has recently made standard cells, hermetically sealed. This retards the formation of oxychloride.

About 15 minutes short circuit is required to bring out the full current of a newly charged battery. The battery should also be short circuited a few seconds, after having been at rest for some time, to ensure absolute constancy of electro-motive force. This battery is particularly adapted for work in which moderate and constant electro-motive force is required—*e.g.*, for testing and signalling purposes on submarine cables and telegraph lines, and by far the best for use on board a cable ship. They occupy very little space, and are not injuriously affected by the rolling of the ship. They are made up in sets of 10 or 20; and 100 cells only occupy a space of 3 ft. 6 in. × 2 ft. × 6 in.

b. Faure's Secondary, or Storage, Battery (see Table VIII.).—A single Faure cell consists of two clean lead plates, each plate being coated with a paste, made by mixing minium (Pb_3O_4) with dilute sulphuric acid (H_2SO_4). The coated plates are then covered with felt cloth, bound or rolled up together, and immersed in a trough containing dilute sulphuric acid. The following chemical reaction takes place at *both* plates between the minium and sulphuric acid, *before* the application of any charging current. $Pb_3O_4 + 2\,H_2SO_4 = PbO_2 + 2\,PbSO_4$

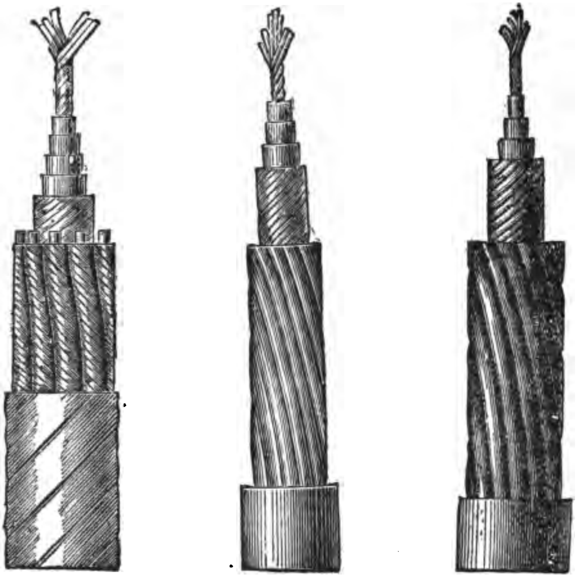
$+2\,H_2O$. The Faure cell is now charged with a current (from a separate battery or dynamo), with an E.M.F. not exceeding 3 volts, when more peroxide of lead, PbO_2, is formed at the positive lead plate, as well as sulphuric acid; thus $PbSO_4+H_2O+O=PbO_2+H_2SO_4$. At the negative plate the PbO_2 and $2\,PbSO_4$ are both reduced to spongy or porous metallic lead, with formation of sulphuric acid and water. Consequently, sulphuric acid is generated during charging at both plates, so that the strength of the solution is fully kept up. When the minium has been fully converted by a number of successive charges and discharges, we have, on again charging the cell, a layer of peroxide of lead adhering to one lead sheet, forming a + plate, and a layer of spongy lead adhering to the other, forming a − plate, with a difference of potential between them = 2 to 2·2 volts. The resistance between the plates being very small, a strong current is produced on joining them through a small external resistance, and 80 per cent. of the energy of the last charge can be obtained in the discharge with newly-formed cells, but with continued use and age the percentage return decreases.

TABLE VIII.—ELECTRO-MOTIVE FORCES OF VARIOUS CELLS.

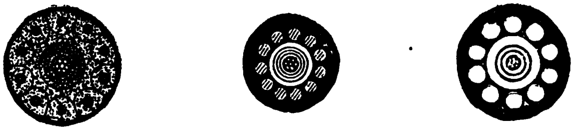
From Gordon and other sources.

	+ Plate.	Porous cell		− Plate.	Volts.
Daniell	Zinc amalg.	Sulphuric acid, 7½ to 1	Saturated solution of copper sulphate	Copper	1·079
"	"	22 to 1	"	"	0·978
"	"	"	Nitrate of copper saturated	"	1·000
"	"	"	Sulphate of copper	"	0·909
"	"	Sulphate of zinc saturated solution	" Saturated solution	"	1·08
Grove	"	Sulphuric acid, 7½ to 1	Nitric acid (fuming)	Platinum	1·956
"	"	Salt water	Nitric acid, sp. gr. 1·33	"	1·904
"	"	Sulphuric acid, 22 to 1	"	"	1·810
"	"	Sulphate of zinc	"	"	1·672
Bunsen	"	Dilute sulphuric acid	Nitric acid	Carbon	1·734
Callan	"	"	"	Cast iron	1·700
Poggendorf	"	"	Chrome mixture	Carbon	{1·796 {2·028
Marié Davy	"	Sulphuric acid, 22 to 1	Paste of sulphate of mercury	"	1·524
"	"	Dilute sulphuric acid	"	"	1·33
Leclanché	"	Solution of sal ammoniac	Binoxide of manganese	"	1·48
DelaRue (p. 334)	Zinc	Chloride of Ammonium		Silver (AgCl)	1·030
Becquerel	Zinc amalg.	Sulphate of zinc	Sulphate of lead	Lead	0·55
Niaudet	"	Common salt	Chloride of lime	Carbon	1·65
Duchesnin	"	"	Perchloride of iron	Lead	1·541
"	Platinum	Dilute sulphuric acid	Dilute sulphuric acid	Platinum	1·79
Planté	Lead	"	"	Lead (spongy)	2· to 2·2
Latimer Clark, Standard cell	Zinc amalg.	Sulphate of zinc	Paste of sulphate of mercury	Mercury	1·457
Howell's manganese; internal res. = 1 ohm (Hockin.)	Zinc amalg.	Ammonic sulphate, 25 grammes crystallised salt to 1 litre water	Sulphuric acid, 1 acid to 5 parts water	Carbon + manganese dioxide + manganese sulphate	2·04
Higgin's cascade, internal res = ·170 ohms.	Zinc in mercury	Chromic acid	Sulphuric acid	Carbon	1·9
Bennet's internal res. = 5 ohms.	Zinc	Potassium Hydroxide (KHO), with distilled water.	Damped with (KHO) and water	Iron can with iron borings.	1·3
Faure's secondary battery. See p. 334 *b*	Lead plate coated with minium.	Dilute sulphuric acid.	Dilute sulphuric acid.	Lead plate coated with minium.	2· to 2·2

FIG. 14.—PLATINO-BRAZILEIRA CABLES, ETC.



(See Tables XII. and XIII.)

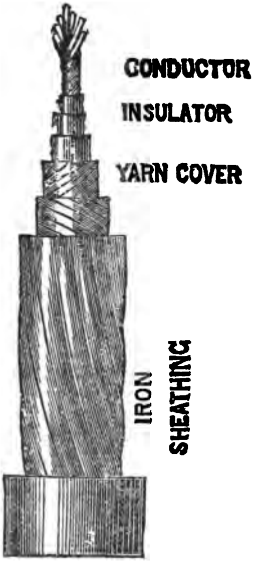


Main Atlantic. For Depths. 500 to 2500 fms.

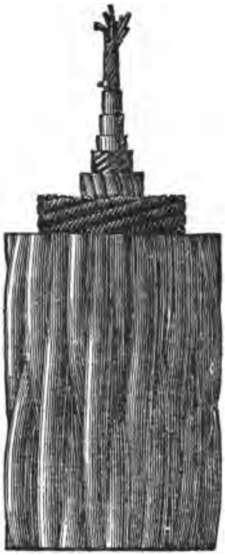
Main Cable. For Depths. 150 to 1200 fms.

Intermediate. For Depths. 40 to 150 fms.

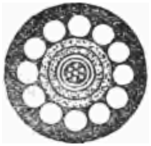
FIG. 14.—PLATINO-BRAZILEIRA CABLES—*continued.*



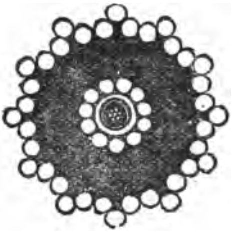
C



D (Types see p. 38.



Light Shore End.
For Sandy Bottom.
Up to 50 fms.



Heavy Shore End.
For Rocky Shore and Strong Currents.
Up to 25 fms.

§ VII—SUBMARINE CABLES.

a. SPECIFICATION FOR PLATINO-BRAZILEIRA CABLE, MADE AND LAID BY MESSRS. SIEMENS BROTHERS, CHARLTON, BETWEEN RIO DE JANEIRO AND CHUY, SOUTH AMERICA. SIR WILLIAM THOMSON AND PROFESSOR FLEEMING JENKIN, CONSULTING ENGINEERS. (See Fig. 14.)

Core.—The core to consist of 7 wires copper strand, covered with gutta-percha. The following are to be the weights of the core :—

Copper.—7 wires laid into a strand, weighing 107 lbs. per knot.

Guttapercha.—3 coatings of guttapercha and Chatterton's compound =150 lbs. per knot.

Main Cable A.—This cable to consist of the following parts :—(1.) Core as above. (2.) A good and sufficient serving of jute yarn, wet and saturated with brine. (3.) Outer covering to consist of 11 galvanised iron wires, of the quality specified below, and the diameter of each wire to be 0·143 inch, or within 2·5 per cent. thereof; the whole to receive 3 coatings of Clark's Compound and 2 layers of jute yarn between ; the whole weight of iron to be not less than 3600 lbs. per knot.

Main Cable B.—The core, served as far as Cable A, to be covered with 10 iron galvanised wires of quality as specified below, the diameter of each wire to be 0·18, or within 2·5 per cent. thereof ; the whole to receive 3 coatings of Clark's Compound, with 2 layers of jute yarn between the coatings, in alternate layers, the total weight to be not less than 5160 lbs. per knot.

Shore End C.—The Conductor and Insulator to be the same as for Cable A, with a sufficient serving of the same materials, covered with 12 galvanised iron wires, 0·238 inch diameter, of the quality specified below, the total weight of iron per knot to be not less than 96 cwts. ; the whole to receive 3 coatings of Clark's Compound, with two layers of jute yarn between the coatings, in alternate lay.

Shore Cable D.—This Shore End Cable shall consist of Cable A, without the outer servings of jute and Clark's Compound, but further served with a well-tarred jute yarn, and sheathed with 12 strands of 3 wires each, of the quality specified below ; the total weight of these wires per knot to be not less than 275 cwts.—that is to say, of not less than 12 strand of 3 wires, 0·230 inch diameter. Each intermediate cable to be finished off with suitable tapers, to be arranged to the satisfaction of the engineers of the Company.

I. **Quality of Materials.**—The iron wire supplied for all the cables shall be of the quality known as **best best** annealed galvanised, and of a quality superior to the ordinary best best, and shall be submitted to such tests for strength and brittleness as may be agreed upon between the engineers and contractors.[*]

A margin of 2·5 per cent. above and below contract weight will be allowed, provided the average weight be adhered to. No wire of brittle quality shall be put into the cables, and the engineers, or their assistants, shall have power to reject any hanks which break frequently in the closing machine, or any of unsatisfactory quality. No weld shall be made in any wire within 12 feet of any other weld of the same, or any other wire of the cable, except in the strands of shore end D.[†]

---

[*] See Table XIII., for Clark, Forde & Co.'s tests, for other wire tests.

[†] 0·143 inch wire was brazed by scarfing the joints and hard soldering them. All other sizes were welded, but they could not be well done, owing to the deteriorating action which the galvanising had upon the iron—*i.e.*, they could not be welded so as to bind into a semicircle and back again, but it was found that the brazing, if carefully effected, and with a good pressure and flow of gas and wind combined, made the better joint.—A. J.

Weight of bundle in lbs.	Diameter of Wire.	No. of twists in 6 in.	Bending and Unbending round a Spindle.
162	0·143 inch.	13	0·572 inch.
...	0·180 „	10	0·720 „
280	0·230 „	6	0·920 „
289	0·238 „	5	0·952 „

II. Cables A, B, C are to be covered, after the wires are laid on, with 3 coatings of mineral pitch and silica, in the proportions of 60 and 40 parts respectively, and with 2 servings of tarred jute yarn laid alternately, the first coating of the compound being (laid) next the wire, then a serving of jute yarn, the compound, then the jute yarn, and lastly, compound. The compound to be applied hot, and the yarn to be laid on immediately after its application. Such special precautions to be taken against injury to the core, in case of the machinery stopping, as the Company's engineers shall direct. The yarn is to be everywhere covered with compound, and the outside smooth and regular.[*]

III. The **Conductors** to consist of a strand of 7 wires of annealed copper of the best quality and manufacture. The interstices in the strand to be completely filled with insulating compound. The mean resistance of the strand, weighing 107 lbs. per knot, to be not more than 12·15 ohms at 75° Fah. No single knot of conductor to have a resistance exceeding the numbers given above by 2·5 per cent.

IV. The **Insulation** resistance of guttapercha core shall not be less, when tested at 75° Fah., than 300 megohms, 14 days after manufacture and after 2 minutes' electrification. If the resistance of any portion of the guttapercha at 75° Fah., at any period of the manufacture, fall below the above specified limit, the cable is to be **rejected.**

V. The **Joints** in the core are to be made by experienced workmen, and no joint at the cable works is, under any circumstances, to be made, except in the presence of one of the Company's inspectors, who will test and pass each joint separately from the rest of the cable. The contractors shall allow time for a thoroughly satisfactory test, 6 **hours** after the joints have been made and kept immersed in water.

VI. The **Serving** shall consist of yarn applied wet and **saturated** with brine.

VII. The **Core** shall be delivered in lengths of not less than 1 **mile**—it shall be immersed in water, of a temperature of 75° Fah., for at least 24 hours before the tests are made. The length of coil shall be given to the Company's engineers. A margin of 2·5 per cent. over the specified weight shall be allowed, but the mean weight of the core for the whole cable must at least equal that of the specified weight. All coils approved of by the Company's engineers shall be re-delivered for further manufacture, and all coils rejected by the engineers shall be retained at the works for inspection till the close of the manufacture. All coils shall be numbered, labelled, and registered, and the engineers shall be kept cognisant of the position and portion of the cable into which each length of core is inserted.

---

[*] The Telegraph Construction and Maintenance Company generally apply an outer serving of 2 of Johnson and Phillips's patent tapes, laid on spirally in opposite directions, and 3 coatings of Clark's compound, the first coating being cool and laid on next the wires.—A. J.

VIII. Special requirements for Company's engineers testing room. . . . . .

IX. The core shall be coiled on drums, and shall be carefully kept until serving is begun, the drums to be carefully protected by iron covers during the transit from the insulating to the sheathing factories—the served core to be kept in tanks under water, the water to be withdrawn from the tanks and replaced by fresh, so often as required by the engineers. The tanks are to be roofed over. Correct indicators are to be attached to the closing machines, showing the exact amount of cable manufactured, and the completed cable is to be marked at every 100 miles in the usual manner, and kept under water as far as possible, both in the factory and on board ship, until submerged, &c., &c.

PREVENTION AGAINST TEREDOES.

In order to prevent the core of submarine cables becoming pierced and damaged by teredoes or other marine borers, the Telegraph Construction and Maintenance Company cover, where thought advisable, the guttapercha of their core with—1st., a serving of strong white canvas tape; 2nd, Muntz metal (or brass taping); 3rd, canvas tape steeped in stearine. The last tape coating prevents galvanic action between the brass taping and the iron sheathing. This has been proved practically in the Eastern Extension and Eastern and South African Companies' cables to be a perfect remedy. Teredoes do not attack india-rubber or Hopper's core injuriously.—A. J.

b. **Cooling mixture for cable joints** (guttapercha), used on board cable ships in tropical climates:—Muriate of ammonia 5 parts, saltpetre 5 parts, water 16 parts; immerse joint and stir mixture well until joint cools.

c. **Grappling.**—Success in grappling for cables greatly depends upon *slowly* and *steadily* dragging the grapnel over the cable ground at right angles to the line of cable (1½ to 2 knots an hour being a good working speed), with just sufficient slack of grapnel rope, length and weight of chain, as well as weight of grapnel, to prevent the latter from jumping, and thus missing ground. A compound steel-wire-manilla grapnel rope (4 by 4), capable of bearing a strain of 15 tons before breaking, joined up in 200 fathom lengths, and 15 fathoms of ⅞ inch chain, with a 2½ cwt. grapnel, forms a good combination for depths up to 800 fathoms. For greater depths, a lighter compound steel-manilla rope, or one entirely of the best manilla, may be used with advantage.* On hard rocky bottom, much time, trouble, and breakage of grappling gear will be saved by using a grapnel with automatically self-relieving prongs. One form is shown in fig. 15, where, on coming in contact with a rock, the longer, or searching prongs give way until the rock is passed, but upon hooking the cable it slips into a well-rounded fillet, formed by shorter prongs, and remains there until elevated to the surface.†

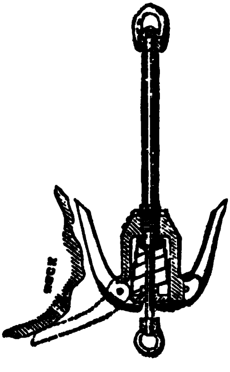


Fig. 15. Cable Grapnel for Rocky Bottom.

---

* Except for, say, 200 fathoms next grapnel, where it might become chafed on bottom.

† See "Cable Grappling," Jamieson, *Jour. Soc. Telegraph Engineers*, vol. viii.

d. TABLE IX.—SUBMARINE CABLES.*

Galvanometer Tests of...............**Cable for 30 mins., during 30 Days' Guarantee. Readings noted every 15 seconds, and means taken for each minute.**

Station......................*Date*.........................

Temperature of Testing Room = 77° Fah. Length 1900 knots.

Time current kept on.	Zinc to Cable 100 cells chl. of silver.†				REMARKS. (For Constant *see* below) Coefficient 1 div.=24526 Megs. Ind. Cap.=·318 Micro-farads.	Time current kept on.	Silver to Cable 100 cells chl of silver.†				REMARKS. (For Constant *see* below.) Coefficient 1 div.=24526 Megs.	Copper Resistance. No. of Cells.	
	Deflections. Shunt 350. Mult. P 21·13.	Dielectric Resistance.					Deflections. Shunt 350. Mult. P 21·13.	Dielectric Resistance.				Total.	Per knot at Fah. Red. to 75° Fah.
		Total.	Per knot.					Total.	Per Knot.				
			at ....F.	Red. to 75° F.					at ....F.	Red. to 75° F.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Min.	No.	M'ohms	M'ohms	M'ohms		Minute.	No.	M'ohms	M'ohms	M'ohms		Ohms.	Ohms.
	Earth current 2 to 3 divs. each side						Earth current 2 to 3 divs. each side.					Mean of 17 readings, with each current.	
1	482	2·408	4570	...		1	485	2·393	4550	...			
,,	424	2 737	5200	...	Calculated from last min.	,,	425	2·731	5190		Calculated from last min.		
&c.	...	...	...	...									
					See abstract form *B*, for extracts from rest of results (noted every minute.)								
30	244	...	9090		Improvement, 73·7 per cent.	30	245	...	9040		Improvement, 73·4 per cent.	8324	4·644

Return *Earth Readings, Zinc* current, taken for 5 minutes. 1 min. = 180 + 244 (30th min.) = 424, which gives deflection, calculated for first min.

Return Earth Readings, Silver Current, taken for 5 mins. 1 min. 180+245=425, which gives deflection calculated for first min.

Then Silver to line (current reversed). Five mins. readings taken. 1 min.=562 − (82 − 5)=485

Then Zinc to line (current reversed). Five minutes' readings taken, 1=564 − (79 − 4) =489.

Tested values at 75° Fah.
G. P. Factory Tests.

C R. per Kt.	4·936 Ohms.
D. R. do.	296 Megs.
Ind. Cap.	·3148 Mfds.

Copper Resistance Tests were taken with slides (R) 10,000 ohms, correct at 15·2° C.

These details are generally printed on back of test sheet.

CONSTANT.

Inserted Resistance . . . . . . 1,000,000 Ohms.
Galvanometer do. 7000 } $\frac{G+S}{S}=59{\cdot}33$. $\frac{GS}{G+S}=118$. ,,
Shunt do. 120 }
Battery (100 cells) chloride of silver . . . . 400 ,,
Deflection . . . . 410·5 divs.
Coefficient . 24526 Megs. for one division with whole Battery.

---

* All these four tables, IX., X., XI. XII., are tests of the same cable.

† The De la Rue chloride of silver battery (100 cells) was short circuited for two minutes before test.

TABLE X.—SUBMARINE CABLES.*

Abstract—Form B.

(Recently Laid.)

Tests of Laid Cable.]

STATION FROM————TO————

An almost precisely similar abstract form was kept of the tests in factory, on board ship after shipment, and before being laid, as well as during paying out.

Section.	Date.	Length in Circuit.	Temperature.		C. R. per knot.		Electrification Tests. Zinc to Cable, 100 cells, De la Rue.					
			Observed.	By C. R.	At Temperature of Cable.	Reduced to 75° Fah.	Time current on.	D R. per knot, observed.			Mean of Readings = R at	Improvement % at……min.
								At				
								1st min.	5th min.	Last min.		
1	2	3	4	5	6	7	8	9	10	11	12	13
		Knots. 1900	Fah.	Fah. 45·7°	Ohms. 4·644	Ohms.	Mins. 30	Megs. 5200	Megs. 6860	Megs. 9080	Mins. 11th	% 73·7

* All these four tables, IX., X., XI., XII., are tests of the same cable.

TABLE X.—*Continued.*

SUBMARINE CABLES.*

(Recently Laid.)

Electrification Tests.						Inductive Capacity per knot.	Loss per cent.		Mean D. R. per knot at 75° F., end one min. calculated from C. R.		Mean Resistances of Core per knot as tested at 75° Fah. G. P. Factory Tests.			REMARKS and Name of Person who took the Tests.
Copper to Cable, 100 cells, De la Rue.														
Time current on.	D. R. per knot, observed.			Mean of Readings =R at	Improvement % at......min.		After one minute.	After......minutes.	Under pressure.	Corrected for pressure.	Copper.	Guttapercha at one minute.	Inductive capacity per knot.	
	At													
	1st min.	5th min.	Last min.											
14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Mins. 30	Megs 5190	Megs. 6860	Megs. 9040	Mins. 11th	% 73·4	Mfds. ·318	% ...	% ...	Megs. ...	Megs. 490	Megs. 4·936	Ohms. 296	Mfds. ·3148	Taken at station by Clark, Forde & Taylor.

* All these four tables, IX., X., XI., XII., are tests of the same cable.

TABLE XI.

SUBMARINE CABLES.*

(Recently Laid.)

ABSTRACT FORM,

Showing general condition of Cable during 30 *days' tests.*

BY CLARK, FORDE & TAYLOR.

1.	Length of cable,	From Cable house, Cable house,			knots	1900
2.	Distance over water, ...				,,	1795·24
3.	Percentage of slack, ...				%	6·3
4.	Depth of water,	Maximum sounding taken, ...			Fms.	1296
		Mean (about) ...			,,	488
5.	Pressure at bottom per square inch,	Maximum,			lbs.	3460
		Mean, ...			,,	1265
6.	Mean copper resistance tested at 75° Fah. per knot (approx.)				ohms.	4·936
7.	Do. after laying,	Total observed, ...			,,	8809
		Do. corrected, ...			,,	8824
		Per knot do., ...			,,	4·644
8.	Mean temperature of cable calculated from C. R.,				Fah.	45·7°
9.	Dielectric resistance,	Mean of both currents, from several days' tests,	Total	1st min. calculated	Megs.	2·72
				1st ,, observed	,,	2·46
				5th ,, ,,	,,	3·58
				10th ,, ,,	,,	3·90
				30th ,, ,,	,,	4·71
			Per knot	1st min. calculated	,,	5168
				1st ,, observed	,,	4674
				5th ,, ,,	,,	6802
				10th ,, ,,	,,	7410
				30th ,, ,,	,,	8947
10.	Electro-static capacity,	Total, ...			Mfds.	604
		Per knot, ...			,,	0·318
11.	Dielectric resistance per knot at 75° Fah. on first manufacture, 1st minute, ...				Megs.	296†
12.	Dielectric resistance per knot reduced to 75° Fahrenheit, 1st minute,	After shipment, tested at mean temp. 51° Fah., ...			,,	467
		On arrival out, tested at mean temp. 71° Fah., ...			,,	476
		After submersion, mean temp. 45·7° Fah., ...			,,	490†

---

* All these four tables, IX., X., XI., XII., are tests of the same cable.

† Improvement in dielectric resistance from time of manufacture to after submersion, 65·5 per cent.

TABLE XII.

e. MECHANICAL DATA OF VARIOUS RECENT TELEGRAPH CABLES.

* *Manufactured and Laid by The Telegraph Construction and Maintenance Co., Limited.*

For Electrical Data, see p. 50.

Cables.	Date.	Length Laid.	Weight per Knot.						Remarks.
		Knots.	Copper.	Insulator. G.P.	Iron.	Jute.	Asphalt, &c., &c.	Complete.	
			lbs.	lbs.	Tons.	Tons.	Tons.	Tons.	
Placentia & St. Pierre,	1872	110	107	140	2·344	·153	...	2·607	Main.
			,,	,,	9·845	·519	1·145	11·619	Shoreends.
St. Pierre & Sydney, ...	,,	182	,,	,,	2·344	·153	...	2·607	Main.
			,,	,,	9·845	·519	1·145	11·619	Shoreends.
Constantinople,	,,	5	,,	,,	1·193	·107	·393	1·803	
England and Spain, ...	1873	619	120	175	9·845	·519	1·505	12·000	Shore.
			,,	,,	5·369	·350	·750	6·600	Intermed.
			,,	,,	2·687	·093	·475	3·382	,,
			,,	,,	1·900	·187	·412	2·630	,,
			,,	,,	·645	·095	·826	1·697	Main.
Vigo & Lisbon,	,,	247	120	175	9·845	·519	1·505	12·000	Shore.
			,,	,,	2·687	·093	·475	3·382	Main.
			,,	,,	5·369	·350	·750	6·600	Intermed.
Ireland and Newfoundland, ...	,,	1876	400	400	17·460	1·684	...	19·50	Shore.
			,,	,,	9·641	·641	1·989	12·628	Intermed.
			,,	,,	3·350	·164	·498	4·369	,,
			,,	,,	2·419	·090	·588	3·454	,,
			,,	,,	·662	·147	1·080	2·246	Main.
Placentia & Sydney, ...	,,	314	107	140	17·460	1·684	...	19·254	Shore.
			,,	,,	9·641	·641	1·989	12·381	Intermed.
			,,	,,	3·350	·164	·498	4·122	Main.
Sydney and Placentia,	,,	280	,,	,,	17·460	1·684	...	19·254	Shore.
			,,	,,	9·641	·641	1·989	12·381	Intermed.
			,,	,,	3·350	·164	·498	4·122	Main.
Neuwerk & Heligoland,	,,	31	107	140	9·514	·666	1·371	11·661	Shore.
			,,	,,	5·917	·325	·691	7·043	Main.
Lisbon and Madeira, ...	,,	613	120	175	9·450	·750	1·337	11·668	Shore.
			,,	,,	2·687	·094	·470	3·382	Intermed.
			,,	,,	1·900	·187	·412	2·630	,,
			,,	,,	·636	·137	·940	1·845	Main.
Alexandria & Crete, ...	,,	359	107	140	9·845	·519	1·145	11·619	Shore.
			,,	,,	5·917	·325	·691	7·043	Intermed.
			,,	,,	1·038	·075	·337	1·56	Main.

All these tables were kindly furnished by W. Shuter, Esq., Manager of The Telegraph Construction and Maintenance Co.

* For Cables prior to 1872, see "Electrical Tables," Clark and Sabine, pp. 256-259.

TABLE XII.—*Continued.*

For Electrical Data, see p. 150.

Cables.	Date.	Length Laid.	Weight per Knot.						Remarks.
		Knots.	Copper.	Insulator. G.P.	Iron.	Jute.	Asphalt, &c., &c.	Complete.	
			lbs.	lbs.	Tons.	Tons.	Tons.	Tons.	
Crete & Zante,	1873	238	107	140	9·845	·5199	1·504	11·978	Shore.
			,,	,,	5·369	·350	·750	6·579	Intermed.
			,,	,,	1·918	·118	·573	2·719	,,
			,,	,,	1·065	·055	·348	1·578	Main.
Zante and Otranto,	1874	187	107	140	9·845	·519	1·504	11·978	Shore.
			,,	,,	5·369	·350	·750	6·579	Intermed.
			,,	,,	1·065	·055	·348	1·578	Main.
Italy & Sicily,	,,	5	107	140	9·495	·605	1·262	11·472	
Jamaica & Porto Rico,	,,	647	107	140	9·495	·605	1·262	11·472	Shore.
			,,	,,	3·185	·129	·406	3·830	Intermed.
			,,	,,	1·145	·095	·297	1·647	Main.
Martinique & Dominica,	,,	37	107	140	9·495	·605	1·262	11·472	Shore.
			,,	,,	3·185	·129	·406	3·830	Intermed.
			,,	,,	1·145	·095	·297	1·647	Main.
Madeira and St. Vincent,	,,	1196	120	175	9·450	·750	1·337	11·668	Shore.
			,,	,,	2·687	·094	·470	3·382	Intermed.
			,,	,,	1·900	·187	·412	2·630	,,
			,,	,,	·636	·137	·940	1·845	Main.
Kilia & Odessa,	,,	349	107	140	5·325	·400	1·051	6·886	Shore.
			,,	,,	2·725	·275	·793	3·903	Intermed.
			,,	,,	1·038	·075	·337	1·560	Main.
St. Vincent & Pernambuco, ...	,,	1844	255	340	9·450	·762	1·337	11·816	Shore.
			,,	,,	1·900	·187	·412	2·766	Intermed.
			,,	,,	1·262	·063	·387	1·979	,,
			,,	,,	·705	·153	1·084	2·209	Main.
Ireland and Newfoundland, ...	,,	1837	400	400	17·460	1·684	...	19·500	Shore.
			,,	,,	3·350	·164	·498	4·122	Intermed.
			,,	,,	·662	·147	1·080	2·246	Main.
Holland, ...	,,	3	107	140	2·278	·203	·387	2·978	
Italy & Sardinia, ...	1875	118	107	140	1·145	·095	·297	1·647	Main.
Yankalilla & Kingscote,	,,	38	107	140	9·845	·650	1·120	11·725	Shore.
			,,	,,	5·325	·400	1·051	6·886	Intermed.
			,,	,,	2·700	·095	·635	3·540	Main.
Australia & New Zealand, ...	1876	1282	107	140	9·845	·650	1·120	11·725	Shore.
			,,	,,	2·700	·095	·635	3·540	Intermed.
			,,	,,	1·060	·080	·450	1·700	,,
			,,	,,	·635	·200	·380	1·325	Main.
Cook's Straits, N.Z.	,,	45	107	166	7·623	·514	1·136	9·618	3 cores.
			107	140	8·412	·587	·635	9·741	Shore.
			,,	,,	4·075	·287	·400	4·872	Main.
Suez & Aden,	,,	1443	120	175	9·951	·838	1·236	12·156	Shore.
			,,	,,	2·848	·101	·435	3·515	Intermed.
			,,	,,	1·867	·146	·392	2·596	,,
			,,	,,	1·156	·101	·376	1·764	Main.

TABLE XII.—*Continued.*

For Electrical Data, see pp. 50, 51.

Cables.	Date.	Length Laid.	Weight per Knot.						Remarks.
		Knots.	Copper.	Insulator. G.P.	Iron.	Jute.	Asphalt, &c., &c.	Complete.	
			lbs.	lbs.	Tons.	Tons.	Tons.	Tons.	
Aden & Bombay, ...	1877	1888	180	240	11·399	·694	·571	12·850	Shore.
			,,	,,	9·813	·414	1·552	11·960	,,
			,,	,,	5·389	·281	·687	6·544	Intermed.
			,,	,,	2·827	·111	·576	3·702	,,
			,,	,,	·626	·201	·254	1·268	Main.
Penang and Rangoon,	,,	853	107	140	9·800	·450	1·650	12·010	Shore.
			,,	,,	2·850	·125	·484	3·569	Intermed.
			,,	,,	1·060	·093	·291	1·554	Main.
Marseilles & Bona, ...	,,	463	107	140	9·800	·650	1·120	11·680	Shore.
			,,	,,	2·900	·244	·440	3·692	Intermed.
			,,	,,	1·062	·144	·297	1·613	Main.
Bona & Malta,	,,	382	107	140	9·800	·650	1·120	11·680	Shore.
			,,	,,	5·337	·550	·475	6·472	Intermed.
			,,	,,	2·900	·244	·440	3·692	,,
			,,	,,	1·062	·144	·297	1·613	Main.
Para & Maranham, ...	1878	309	107	140	8·412	·587	·635	9·741	Shore.
			,,	,,	4·075	·287	·400	4·872	Intermed.
			,,	,,	2·900	·125	·237	3·372	Main.
TorpedoCables,	,,	289	98	116	·718	·064	·447	1·324	
			,,	,,	1·117	·150	·682	2·340	4 cores.
			,,	,,	·856	·056	·285	1·292	
Alexandria & Cyprus, ...	,,	327	107	140	9·800	·650	1·120	11·680	Shore.
			,,	,,	2·900	·244	·440	3·692	Intermed.
			,,	,,	1·062	·144	·297	1·613	Main.
Penang and Malacca, ...	1879	274	107	140	10·350	·675	1·026	12·161	Shore.
			,,	,,	2·803	·225	·554	3·692	Main.
Natal & Delagoa, ...	,,	344	107	140	13·647	·575	...	15·652	Shore.
			,,	,,	10·350	·675	1·026	12·161	,,
			,,	,,	5·230	·400	·781	6·521	Intermed.
			,,	,,	2·803	·225	·554	3·692	Main.
			,,	,,	·850	·050	·362	1·372	,,
Delagoa and Mozambique	,,	966	107	140	10·350	·675	1·026	12·161	Shore.
			,,	,,	5·230	·400	·781	6·521	Intermed.
			,,	,,	2·803	·225	·557	3·692	,,
			,,	,,	·862	·075	·337	1·387	Main.
			,,	,,	·850	·050	·362	1·372	,,
			,,	,,	·625	·187	·517	1·442	,,
Malacca and Singapore,	,,	116	107	140	10·350	·675	1·026	12·161	Shore.
			,,	,,	2·803	·225	·554	3·692	Main.
Germany & Norway, ...	,,	251	100	125	16·524	·487	1·225	18·536	Shore.
			,,	,,	4·135	·260	·430	5·126	Main.
			,,	,,	2·375	·150	·406	3·162	,,
Mozambique & Zanzibar,	,,	631	107	140	10·350	·675	1·026	12·161	Shore.
			,,	,,	5·230	·400	·781	6·521	Intermed.
			,,	,,	2·803	·225	·554	3·692	,,
			,,	,,	·850	·050	·362	1·372	Main.
			,,	,,	·625	·187	·517	1·442	,,

TABLE XII.—*Continued.*

For Electrical Data, see p. 51.

Cables.	Date.	Length Laid.	Weight per Knot.						Remarks.
		Knots.	Copper.	Insulator. G.P.	Iron.	Jute.	Asphalt, &c., &c.	Complete.	
			lbs.	lbs.	Tons.	Tons.	Tons.	Tons.	
Singapore & Java, ...	1879	919	107	140	10·350	·675	1·026	12·161	Shore.
			"	"	5·230	·400	·781	6·521	Intermed.
			"	"	2·803	·225	·554	3·692	Main.
			"	"	1·772	·115	·500	2·497	"
Aden & Zanzibar, ...	"	1908	250	250	10·350	·675	1·026	12·274	Shore.
			"	"	5·230	·400	·781	6·634	Intermed.
			"	"	3·360	·145	·616	4·344	"
			"	"	·625	·187	·517	1·442	Main.
			"	"	1·112	·200	·367	1·902	"
Java & Australia, ...	1880	1131	107	140	10·350	·675	1·026	12·161	Shore.
			"	"	2·803	·225	·554	3·692	Intermed.
			"	"	·850	·050	·362	1·372	Main.
Wanganui & Wakapuaka,	"	108	107	140	11·402	·518	...	12·030	Shore.
			"	"	2·847	·145	·616	3·718	Main.
Hong Kong and Luzon,	"	528	107	140	10·350	·675	1·026	12·161	Shore.
			"	"	5·230	·400	·781	6·521	Intermed.
			"	"	2·803	·225	·554	3·692	"
			"	"	·880	·070	·451	1·511	Main.
			"	"	·710	·212	·518	1·550	"
Placentia & St. Pierre,	"	109	107	140	14·770	·625	...	15·725	3 core.
			"	"	7·700	·600	·850	9·480	"
			"	"	4·650	·200	·575	5·755	"
Ireland and Newfoundland, ...	"	1423	300	300	·860	·115	·725	1·967	Main.
			"	"	·720	·115	·705	1·807	"
England and Norway, ...	"	423	180	200	11·585	·260	1·045	13·100	Shore,
			"	"	7·780	·405	1·000	9·355	Intermed.
			"	"	3·450	·225	·662	4·507	"
			"	"	2·400	·137	·570	3·277	Main.
			"	"	14·100	·260	1·085	15·615	
Norway and Sweden,	"	94	180	200	2·400	·137	·570	3·277	Main.
			"	"	7·780	·405	1·000	9·355	Intermed.
St. Pierre & Sydney, ...	"	185	107	140	14·770	·625	...	15·725	3 core.
			"	"	7·700	·600	·850	9·480	"
			"	"	4·650	·200	·575	5·755	"
Singapore & Batavia, ...	1881	537	107	140	10·350	·675	1·026	12·161	Shore.
			"	"	2·803	·225	·554	3·692	Main.
Trieste and Corfu, ...	"	550	130	130	10·000	·600	1·015	11·731	Shore.
			"	"	5·340	·400	·727	6·583	Intermed.
			"	"	2·900	·150	·587	3·753	"
			"	"	1·110	·057	·371	1·654	Main.
Valentia, Greitseil,	1882	841	130	130	11·900	·550	·400	12·966	Shore.
			"	"	5·600	·350	·633	6·729	Intermed.
			"	"	2·78 *	·125	·499	3·520	Main.

* W. Clifford, Chief Engineer.

f. TABLE XIII.—SUBMARINE CABLES.

Results of tests of Iron Wire used for sheathing Cables, by Clark, Forde, & Co., from a large number of averages taken between 1878 and 1882.*

Name of Maker.	Description.	Size of Wire.		Breaking Strain		Elongation, per cent.	Torsion Test. No. of turns round itself and back.	Used in Cable.
		B. W. G.	Dia.	of Wire.	per sq. inch.			
			Inches.	lbs.	Tons.		Round. Back.	
... ...	Iron galvanized, ...	6	·200	2266	32	18·3	3 — 0	Duplicate Australian.
Felton & Guillaume,	Homo. iron galvanized,	13	·100	1113	63	7·1	3 — 3	,, ,,
... ...	,, ,,	13	·100	1370	78	5·7	3 — 2½	Eastern and South African.
Johnston & Nephew,	,, ,,	13	·098	1392	82	5·1	3 — 2½	Hong Kong, Manilla.
Felton & Guillaume,	,, ,,	13	·099	1286	75	5·5	3 — 3	,, ,,
... ...	,, ,,	13	·099	981	57	4·9	3 — 3	,, ,,
Felton & Guillaume,	Iron galvanized, ...	6	·200	2142	30	18·1	3 — 0	,, ,,
Johnston & Nephew,	,, ,,	6	·198	2052	30	19·0	3 — 0	,, ,,
Felton & Guillaume,	Homo. iron galvanized,	13	·098	1094	70	5·2	3 — 3	Atlantic, 1880.
G. & F. Rogers, ...	,, ,,	13	·101	1038	63	3·	3 — 3	,, ,,
Johnston & Nephew,	,, ,,	13	·098	1384	89	4·9	3 — 3	,, ,,
Fox & Co., ...	,, ,,	13	·100	959	59	3·5	3 — 3	,, ,,
Felton & Guillaume,	Steel galvanized, ...	13	·099	1641	102	5·7	3 — 2	,, ,,
,, ,,	Iron ,, ...	6	·200	2213	33	14·5	3 — 0	Placentia, Sydney, 1880.
Johnston & Nephew,	,, ,, ...	6	·197	2069	31	18·5	3 — 0	,, ,, ,,
,, ,,	,, ,, ...	8	·165	1388	30	17·8	3 — 0	... ...
Hill & Co., ...	,, ,, ...	8	·160	1262	29	18·	3 — 0	... ...
Felton & Guillaume,	,, ,, ...	8	·169	1531	32	15·7	3 — 0	... ...
,, ,,	,, ,, ...	4	·240	3097	32	18·	3 — 0	Placentia, Sydney, 1880.
,, ,,	,, ,, ...	6	·201	2136	31	16·5	†3 — 1	Greitseil, Valentia, 1882.

* For tests of iron wire used for Land Lines see Table XVI., p. 55, also "Telegraphy," by Preece & Sievewright, p. 178; "Practical Telegraphy," by Culley, p. 151; "Telegraphic Construction," by Douglas, p. 210.

† The twist test is now always applied besides bending and unbending the wire round itself.
No. 6 B.W.G., last line, gave a mean of 13·5 twists in a length of 6 inches.

The weight per knot of No. 4 B.W.G. iron wire = 873 lbs. | The weight per knot of No. 8 B.W.G. iron wire = 450 lbs.
,, ,, 6 ,, ,, = 622 ,, | ,, ,, 13 ,, ,, = 144 ,,—A. J.

TABLE XIV.

g. ELECTRICAL DATA OF VARIOUS RECENT TELEGRAPH CABLES

* *Manufactured and laid by The Telegraph Construction and Maintenance Company, Limited.*

Cable. (For mechanical data see pp. 45, 46.)	Date.	Length laid, knots.	Electrical values at 24° Cent.			
			Conductor.		Dielectric (G.P.)	
			Resistance per knot, ohms.	Specific conductivity, pure copper=100	Resistance per knot, megohms.	Electro-static capacity per knot, Microfarads
Placentia and St Pierre,	1872	110	11·930	93·4	378	·303
St. Pierre and Sydney, .	,,	182				
Constantinople . .	,,	5	...	...	...	...
England and Spain, .	1873	619	10·528	94·4	321	·296
Vigo and Lisbon . .	,,	247				
Ireland and Newfoundland,	,,	1876	3·167	94·1	254	·353
Placentia and Sydney, .	,,	314	12·070	92·3	451	·317
Sydney and Placentia, .	,,	280				
Neuwerk and Heligoland,	,,	31	11·879	93·8	262	·312
Lisbon and Madeira, .	,,	613	10·567	94·0	296	·297
Alexandria and Crete, .	,,	359	11·780	94·6	335	·307
Crete and Zante, . .	,,	238	11·668	95·5	258	·309
Zante and Otranto, .	1874	187	11·553	96·4	256	·305
Italy and Sicily, . .	,,	5	...	...	...	...
Jamaica and Porto Rico,	,,	647	11·535	96·7	274	·306
Martinique and Dominica,	,,	37				
Madeira and St. Vincent,	,,	1196	10·436	95·2	285	·297
Kilia and Odessa, . .	,,	349	11·722	95·1	278	·303
St. Vincent & Pernambuco,	,,	1844	4·836	96·7	312	·302
Ireland and Newfoundland,	,,	1837	3·135	95·1	282	·332
Holland, ...	,,	3	...	...	...	...
Italy and Sardinia, .	1875	118	12·024	92·7	373	·296
Yankalilla and Kingscote,	,,	38	11·641	95·8	228	·300
Australia and New Zealand,	1876	1282	11·708	95·2	273	·300
Cook's Straits, N.Z., .	,,	45	11·851	94·0	417	·307
Suez and Aden, . .	,,	1443	10·180	97·6	333	·301
Aden and Bombay, .	1877	1888	6·800	97·4	344	·314

NOTE.—These tables were kindly furnished by William Shuter, Esq., Manager of The Telegraph Construction and Maintenance Company.

* For cables prior to 1872, see "Electrical Tables," Clark and Sabine, pp. 252, 253.

TABLE XIV.—*Continued.*

Cable. (For mechanical data see pp. 47, 48.)	Date.	Length laid, knots.	Electrical values at 24° Cent.			
			Conductor.		Dielectric (G.P.)	
			Resistance per knot, ohms.	Specific conductivity, pure copper = 100.	Resistance per knot, megohms.	Electro-static capacity per knot, Microfarads.
Penang and Rangoon, .	1877	853	11·561	96·4	341	·308
Marseilles and Bona, .	,,	463	11·738	94·9	590	·315
Bona and Malta, . .	,,	382	11·644	95·7	618	·302
Para and Maranham, .	1878	309	11·739	94·9	493	·301
Torpedo Cables, .	,,	289	12·609	96·5	339	·309
Alexandria and Cyprus,	,,	327	11·740	94·9	382	·281
Penang and Malacca, .	1879	274	11·610	96·0	442	·282
Natal and Delagoa Bay,	,,	344	11·586	96·2	461	·282
Delagoa and Mozambique,	,,	966	11·693	95·3	438	·284
Malacca and Singapore, .	,,	116	11·643	96·0	425	·286
Germany and Norway, 3 Conductors, .	,,	251	1, 12·499	95·4	357	·285
			2, 12·477	95·6	342	·286
			3, 12·487	95·5	351	·285
Mozambique and Zanzibar,	,,	631	11·634	95·8	391	·282
Singapore and Java, .	,,	919	11·576	96·3	378	·282
Aden and Zanzibar, .	,,	1908	4·935	96·7	296	·314
Java and Australia, .	1880	1131	11·644	95·7	345	·282
Wanganui and Wakapuaka	,,	108	11·378	97·9	409	·281
Hong Kong and Luzon, .	,,	528	11·453	97·3	456	·280
Placentia and St. Pierre, 3 Conductors, .	,,	109	1, 11·442	97·4	517	·282
			2, 11·414	97·6	494	·282
			3, 11·446	97·4	502	·282
Ireland and Newfoundland,	,,	1423	4·161	95·5	478	·315
England and Norway, .	,,	423	6·864	96·5	500	·303
Norway and Sweden .	,,	94	6,733	98·4	440	·303
St. Pierre and Sydney, 3 Conductors, .	,,	185	1, 11·414	97·6	651	·282
			2, 11·387	97 9	600	·282
			3, 11·422	97·6	613	·282
Singapore and Batavia, .	1881	537	11·297	98·7	709	·316
Trieste and Corfu, .	,,	550	9·155	100·0	658	·352
Valentia and Greitseil, .	1882	841	9·098	100·0	567	·354

---

* Willoughby Smith, Electrician-in-Chief.

TABLE XV.—*g.* TESTS OF ATLANTIC CABLES, ETC., MADE AND LAID BY MESSRS. SIEMENS, BROTHERS & CO.

(*From Special Reports and "Electrical Review."*)

Cable.	When laid.	Total length, knots.	Copper Resistance, in Siemens' Units.			Electro-static Capacity, in Microfarads.			Insulation Resistance, in Million Siemens' Units.			Tests taken by, and Date.
			Total.	Per knot.	Mean from Factory Tests per knot at 75° Fah.	Total.	Per knot.	Mean from Factory Tests per knot at 75° Fah.	Total, 1st min.	Per knot, 1st min.	Mean from Factory Tests per knot at 75° Fah., 1st min.	
Direct United States, ...	1875	2422·56	7312	3·018	...	987·6	·4077	...	2·26	5,475	...	Fife Jamieson, 9/2/76.
American Telegraph and Cable Co., ...	1881	2517·76	8014	3·184	3·466	887	·352	·3720	7·85	19,770	510	Frank Jacob, 1/7/82.
Do., do.,	1882	2562·70	8264	3·225	3·509	925	·361	·3657	7·4	18,970	508	Do., do.
									Per Knot in Megohms.			
	Aug.		Ohms.	Ohms.	Ohms.				1st min.	10th min.	1st min.	
Djeddah to Souakin (Red Sea). Mean Temp. of Cable, 66° F.	1882	187·66	2115	11·27	11·49	56·18	·2994	·2984	9,382	18,760	2140	Frank Jacob, 21/10/82.

h. FORMULA FOR ASCERTAINING THE STRESS WHEN LAYING A SUBMARINE CABLE, USING ORDINARY DYNAMOMETER.

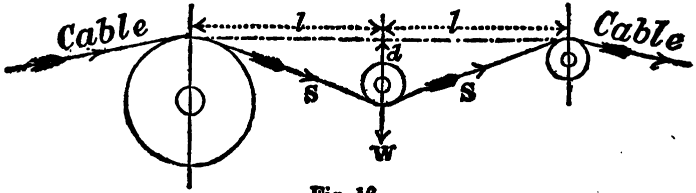


Fig. 16.

S = stress on cable, in cwts. (to be found.)
W = weight of dynamometer pulley, crosshead, &c., in cwts.
l = horizontal length between centre of dynamometer and where cable touches after guide sheave (in inches).
d = deflection of dynamometer pointer from horizontal line (*l*) (in inches).

By parallelogram of forces $S = \frac{W\sqrt{l^2 + d^2}}{2\,d}$ (cwts.)

$$\therefore d = \frac{W\,l}{\sqrt{4\,S^2 - W^2}} \text{ (inches).}$$

Since the stresses and deflections of dynamometer are in inverse ratio to one another, and W and *l* are constant, it is only necessary to work out one example for *d*; plot it off on the dynamometer scale, and mark the others in the inverse ratio,—*i.e.*, for double the stress half the deflection.

i. AVERAGE WORKING SPEED THROUGH LONG SUBMARINE CABLES, WITH SIR WM. THOMSON'S SIPHON RECORDER AND MIRROR GALVANOMETER.

$$S = c\,d^2\,\frac{\log D - \log d}{l^2} = c\;70{\cdot}4\;w\,\frac{\log\sqrt{70{\cdot}4\,w + 491\,W} - \log\sqrt{70{\cdot}4\,w}}{l^2}$$

(See p. 21, Art. 5. and p. 29, Art. 6.)

Where S = speed in letters per minute.
D = diameter of dielectric in mils. (·001 inch).
d = diameter of conductor in mils. (·001 inch).
W = weight of dielectric in lbs. per knot.
w = weight of conductor in lbs. per knot.
l = length of cable in knots.

c = a constant determined by experiment = 28000, from a number of experiments on cables with Willoughby Smith's improved guttapercha, and with 95 °/° purity of copper conductor.

E.g Using the data for the Ireland-Newfoundland cable, given at p. 46 Table XII., we get S = 105 letters per minute.

The constant (*c*) for ordinary guttapercha, or any other form of dielectric, will be in the inverse ratio of its electro-static capacity per knot to that of W. Smith's (see pp. 29, 31).

If R = the total resistance of the cable conductor in ohms, as measured after submersion, and K = the total capacity in microfarads.

Then $$S = \frac{c_1}{R \cdot K} \text{ (in letters per minute).}$$

Where c_1 = a constant determined by experiment = 36×10 , from a number of experiments with W. Smith's core, with 95 °/° purity of conductor. Testing the above-mentioned Ireland-Newfoundland cable (see p. 50, Table XIV.), by this formula $S = 106$ letters per minute.

Limit of Speed.—Automatic senders have not proved as yet very successful on cables, and as the average working limit of speed of a good telegraphist is 135 letters per minute with the Siphon Recorder, a submarine cable need not be designed, according to the above formula, to exceed this in carrying capacity.

Duplex increases the total carrying capacity by about 90 °/°, and manual translation on two sections along with duplex by about 150 °/°, but manual translation on three sections is not successful.

Words per Minute.—In estimating the speed of signalling in words per minute, the number of letters to the word should always be stated to prevent ambiguity. Hitherto it has been usual to take the length of a word as 5 letters, but from the mean of a large number of telegraph messages, it has been found that 7 letters go to the word.

The Speed with Mirror Galvanometer, if worked by very first-class mirror clerks, is slightly greater than that with the Siphon Recorder, but the average is about the same. Preference is now universally given to the recorder, on account of its many advantages—such as permanent record of signals, fewer and less skilled clerks required, and it is much less trying to the eyes of the operator than the mirror system.

The Morse Recorder, when worked with cables, has a speed of about $\frac{1}{14}$ that of the Siphon Recorder. It can, therefore, be used only with short cables of, say, under 400 knots (with $w = 107$ lbs. and $W = 140$), but if worked in connection with the Brown-Allan relay, the speed is increased, and it may be advantageously used with longer cables. See "Working of the Brown-Allan Relay," by Mance, *Journal of the Society of Telegraph Engineers*, Vol. XI., No. 42.

§ VIII.—AERIAL LAND LINES.

a. INSULATOR FOR TELEGRAPH LINES, MESSRS. JOHNSON & PHILLIPS

These insulators are designed to prevent surface leakage.

An insulating fluid (S), which will not support a film of dust or moisture, is placed in a recess formed in the porcelain, and well protected from the weather.

In this way a fluid surface is interposed between "line" and "earth," which is always clean, dry, and highly insulating in the dampest weather.

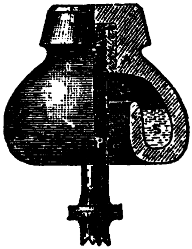


Fig. 17.

An insulation many hundred times higher than that given by the ordinary forms of insulators now in general use is thus obtained. The employment of these insulators on coast lines, where the porcelain quickly becomes coated with a conducting film of salt, is found very beneficial.

TABLE XVI.—IRON WIRE FOR LAND LINES.*

Birmingham Wire Gauge.	Diameter.		Area of Section.	Weight of 100 yards.	Weight of 1 mile.	Length of 1 cwt.	Breaking Strain.	
							Hard Wire.	Soft Wire.
	Inches.	Milli-metres.	Sq. in.	Lbs.	Lbs.	Yards.	Lbs.	Lbs.
00	0·363	9·21	0·103	102·00	1794	110	8600	6000
0	0·331	8·40	0·086	84·72	1490	132	7100	4750
1	0·300	7·61	0·071	68·75	1210	162	6000	4000
2	0·280	7·11	0·062	59·90	1054	187	4850	3400
3	0·260	6·60	0·053	51·65	909	215	4000	2900
4	0·240	6·10	0·045	44·00	775	255	3400	2500
5	0·220	5·59	0·038	37·00	651	303	2950	2200
6	0·200	5·08	0·031	30·56	538	361	2500	1800
7	0·185	4·69	0·0265	26·15	461	428	2200	1520
8	0·170	4·31	0·023	22·10	389	509	1750	1200
9	0·155	3·93	0·0195	18·36	323	609	1500	950
10	0·140	3·55	0·016	14·97	264	747	1200	820
11	0·125	3·17	0·0125	11·95	211	939	820	650
12	0·110	2·79	0·010	9·24	163	1244	710	510
13	0·095	2·41	0·0071	7·05	124	1589	640	400
14	0·085	2·15	0·0057	5·51	97	2031	510	350
15	0·075	1·92	0·0044	4·29	76	2608	410	300
16	0·065	1·65	0·0033	3·22	57	3473	350	200
17	0·057	1·44	0·0026	2·48	44	4515	280	150
18	0·050	1·27	0·0020	1·91	34	5600	200	115
19	0·045	1·14	0·0016	1·55	27	7246	150	85
20	0·040	1·01	0·0013	1·22	21	9168	110	65
21	0·035	0·88	0·0010	0·94	17	11980	85	50
22	0·030	0·76	0·0007	0·69	12	16300	65	40

The above table has been supplied by Messrs. Johnson and Nephew, of Manchester; the *soft* wire is that manufactured by them expressly for telegraphic purposes.

Birmingham Wire Gauge.—The diameters of the several gauges must be considered approximate only. There is no authorised standard, and the sizes of different makers vary considerably. (See Table XVIII., p. 58, for B.W.G.)

---

* From "Practical Telegraphy," by Culley.

TABLE XVII.—OVERHEAD LINES.

By Von Fischer-Treuenfeld, see "The Electrician," May, 1882.

Dip and Span Table for Telegraph Wires at all Temperatures and in all Countries.

Wire when at lowest probable Temperature.			Length of Wires and Dip at Temperatures above the lowest probable Temperatures.									
			10° C. above lowest Temperature.		20° C. above lowest Temperature.		30° C. above lowest Temperature.		40° C. above lowest Temperature.		50° C. above lowest Temperature.	
Span in feet.	Length of Wire in feet.	Dip in feet.	Length in feet	Dip.	Length in feet.	Dip.	Length in feet.	Dip.	Length in feet	Dip.	Length in feet	Dip.
200	200·012	0·94	200·037	1·67	200·059	2·10	200·087	2·55	200·112	2·90	200·137	3·20
300	300·039	2·10	300·076	2·92	300·114	3·58	300·150	4·11	300·187	4·58	300·224	5·02
400	400·096	3·75	400·149	4·73	400·198	5·45	400·255	6·18	400·308	6·80	400·361	7·36
500	500·181	5·86	500·241	6·72	500·303	7·54	500·361	8·23	500·421	8·88	500·481	9·49
600	600·317	8·44	600·394	9·41	600·468	10·27	600·548	11·11	600·625	11·85	600·702	12·57
700	700·512	11·49	700·596	12·51	700·672	13·28	700·764	14·16	700·848	14·92	700·932	15·64
800	800·750	15·00	800·848	15·95	800·947	16·86	801·044	17·70	801·142	18·51	801·240	19·30
900	901·067	18·98	901·178	19·94	901·292	20·84	901·340	21·27	901·511	22·58	901·622	23·40
1000	1001·460	23·43	1001·583	24·36	1001·746	25·59	1001·829	26·19	1001·952	27·06	1002·075	27·90
1100	1101·949	28·36	1102·066	29·33	1102·221	30·27	1102·360	31·20	1102·497	32·09	1102·634	32·96
1200	1202·531	33·75	1202·678	34·72	1202·796	35·47	1202·972	36·57	1203·119	37·46	1203·266	38·21
1300	1303·216	39·61	1303·380	40·59	1303·521	41·43	1303·708	42·52	1303·872	43·45	1304·036	44·36
1400	1404·020	45·94	1404·193	46·92	1404·365	47·87	1404·539	48·82	1404·712	49·74	1404·885	50·64
1500	1504·945	52·73	1505·135	53·82	1505·320	54·70	1505·515	55·69	1505·705	56·65	1505·895	57·58
1600	1606·000	60·00	1606·197	60·98	1606·395	61·94	1606·591	62·89	1606·788	63·82	1606·985	64·74
1700	1707·194	67·73	1707·400	68·68	1707·606	69·63	1707·812	70·53	1708·012	71·04	1708·224	71·99
1800	1808·534	75·93	1808·752	76·86	1808·970	77·81	1809·188	78·75	1809·406	79·68	1809·624	80·59
1900	1910·045	84·60	1910·275	85·56	1910·505	86·51	1910·735	87·45	1910·965	88·39	1911·195	89·31
2000	2011·719	93·75	2011·967	94·74	2012·215	95·71	2012·463	96·68	2012·711	97·64	2012·959	98·59
1	2	3	4	5	6	7	8	9	10	11	12	13

b. DIP AND SPAN TABLES FOR TELEGRAPH WIRES.

BY R. VON FISCHER-TREUENFELD.

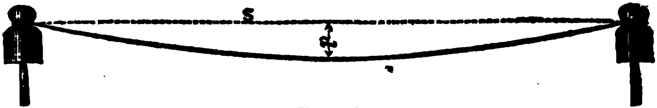


Fig. 18.

A telegraph wire suspended between two supports of equal height forms a curved line, "the catenary," depending upon the following conditions:—

S = span, or direct distance between the two supports.
l = actual length of wire between the two supports.
d = dip of wire.
W = weight of one foot of wire.
b = tension of wire at the lowest point of the curve.

The mathematical deduction of these unknown quantities is to be found in many text-books of telegraphy, and the following equations only relate to the practical calculation of dip and span, viz.:—

$$(1.)\quad d=\frac{W\,.\,S^2}{8\,.\,b}\qquad(2.)\quad l=S+\frac{8\,.\,d^2}{3\quad S}\qquad(3.)\quad d=\sqrt{\frac{3S\,(l-S)}{8}}$$

The preceding table is so arranged that the dip required for any span between 200 and 2000 feet can be read off without calculation. A change of temperature causes either an increase or decrease in the length (l) of the wire, the dip (d), and the tension (b). The table gives the necessary allowance which must be made for any decrease of temperature after the day of the erection of any given span. The wire must be erected under the following condition, viz.,—that after it has contracted to its minimum of length, under the action of the lowest temperature of the coldest winter day, the limit of tension (b), which represents a certain fraction of the breaking strain, must not be exceeded.

This fraction is generally one-third the actual breaking strain; and taking for illustration the P.O. standard wire, No. 8 B.W.G., of ·170-inch diameter, with a weight of 396 lbs. per statute mile, and 1200 lbs. actual minimum breaking strain, the maximum tension (b) of the suspended wire, during its lowest winter temperature, ought not to exceed $b = 400$ lbs. The weight of 1 foot of this wire is $W = 0{\cdot}075$ lb.

TABLE XVIII.

TABLE OF THE BIRMINGHAM WIRE GAUGE.

No. B. W. G.	d= diam. in inches.	d^2	Sect. area in sq. ins.	No. B. W. G.	d= diam. in inches.	d^2	Sect. area in sq. ins.
1 circ. in.	1·000	1·0000	·7854	13½	·089	·0079	·00622
0000	·454	·2061	·16188	14	·083	·0069	·00541
000	·425	·1806	·14186	14½	·077	·0059	·00466
00	·380	·1444	·11341	15	·072	·0052	·00407
0	·340	·1156	·09079	15½	·068	·0046	·00363
1	·300	·0900	·07068	16	·065	·0042	·00332
2	·284	·0807	·06335	17	·058	·00336	·00264
3	·259	·0671	·05268	18	·049	·00240	·00188
4	·238	·0566	·04449	19	·042	·00176	·00138
5	·220	·0484	·03801	20	·035	·00123	·00096
5½	·211	·0445	·03497	21	·032	·00102	·00080
6	·203	·0412	·03236	22	·028	·00078	·00061
6½	·191	·0365	·02865	23	·025	·00063	·00049
7	·180	·0324	·02545	24	·022	·00048	·00038
7½	·172	·0269	·02324	25	·020	·00040	·00031
8	·165	·0272	·02138	26	·018	·00032	·00025
8½	·156	·0243	·01911	27	·016	·000256	·00020
9	·148	·0219	·01720	28	·014	·000196	·00015
9½	·141	·0199	·01561	29	·013	·000169	·00013
10	·134	·0180	·01410	30	·012	·000144	·00011
10½	·127	·0161	·01267	31	·010	·000100	·000078
11	·120	·0144	·01131	32	·009	·000081	·000063
11½	·114	·0130	·01021	33	·008	·000064	·000050
12	·109	·0119	·00933	34	·007	·000049	·000038
12½	·102	·0104	·00817	35	·005	·000025	·000019
13	·095	·0090	·00708	36	·004	·000016	·000012

§ IX.—TABLE XIX.—*a.* HIGH CONDUCTIVITY INSULATED ELECTRIC LIGHT CABLES.

THE INDIA-RUBBER, GUTTAPERCHA, AND TELEGRAPH WORKS COMPANY (LIMITED).

PARTICULARS OF CONDUCTORS.						CLASS A.						CLASS B.						CLASS C.					
						LIGHT INSULATION *Suitable for Aërial use* ¼ megohm per 1000 yds. at 60° F			LIGHT INSULATION *drawn into Lead Pipe.* 3 megohms per 1000 yds. at 60° F.			MEDIUM INSULATION, *Suitable for Dry Situations.* 10 megohms per 1000 yds. at 60° F.			MEDIUM INSULATION, *drawn into Lead Pipe.* 15 megohms per 1000 yds. at 60° F.			HIGH INSULATION, *Suited for Damp places, Railway Tunnels, &c.* 100 megohms per 1000 yds. at 60° F.			HIGH INSULATION, *drawn into Lead Pipe.* 150 megohms per 1000 yds. at 60° F.		
						Particulars of Cable.			Particulars of Cable.			Particulars of Cable.			Particulars of Cable.			Particulars of Cable.			Particulars of Cable.		
Number of Strands in Conductor.	Diameter of each Strand.	Approximate Size in B. W. G. of each Strand of Conductor.	Diameter of Conductor after Stranding.	Weight of Conductor per 1,000 Yards length.	Electrical Resistance per 1,000 Yards at 60° Fah.	Pattern Number.	Diameter of Cable.	Weight of Cable. per 1000 Yards.	Pattern Number.	Diameter of Cable.	Weight of Cable per 1000 Yards.	Pattern Numbers.	Diameter of Cable.	Weight of Cable per 1000 Yards.	Pattern Number.	Diameter of Cable.	Weight of Cable per 1000 Yards.	Pattern Number.	Diameter of Cable.	Weight of Cable. per 1000 Yards.	Pattern Number.	Diameter of Cable.	Weight of Cable per 1000 Yards.
	Inch	B.W.G. No.	Inch.	lbs.	Ohms		Inch.	lbs.		Inch.	lbs.		Inch.	lbs		Inch.	lbs.		Inch	lbs.		Inch.	lbs.
7	·036	20	·108	84	3·457	6792	·18	121	6801	·26	559	6809	·18	127	6817	·26	564	6825	·29	236	6833	·37	876
7	·049	18	·147	157	1·859	6793	·25	231	6802	·33	798	6810	·25	239	6818	·33	806	6826	·37	391	6834	·45	1183
7	·064	16	·192	268	1·090	6794	·33	375	6803	·41	1093	6811	·33	392	6819	·41	1110	6827	·44	600	6835	·52	1506
7	·072	15	·226	343	·851	6795	·37	472	6804	·45	1270	6812	·37	502	6820	·45	1350	6828	·48	746	6836	·56	1760
12	·064	16	·266	458	·644	6796	·44	659	6805	·54	1623	6813	·46	692	6821	·54	1656	6829	·57	1054	6837	·65	2236
14	·064	16	·283	541	·541	6797	·49	786	6806	·57	1808	6814	·49	826	6822	·57	1848	6830	·61	1250	6838	·69	2493
19	·064	16	·330	726	·403	6798	·56	1057	6807	·64	2200	6815	·56	1109	6823	·64	2251	6831	·67	1524	6839	·75	2890
19	·072	15	·360	933	·313	6799	·63	1310	6808	·71	2589	6816	·63	1376	6824	·71	2655	6832	·74	1847	6840	·82	3352

b. Electric Lights.—

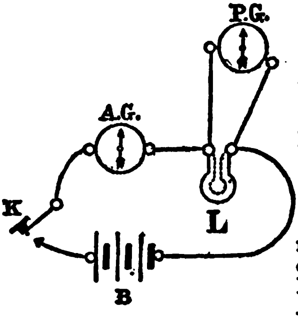


Fig. 19.

L = the electric lamp (arc or incandescent).
B = the generator of electricity (battery or dynamo).
K = Key for completing the circuit.
A G = Ampere galvanometer of very low resistance, for measuring the current strength (C) in amperes.
P G = potential galvanometer of high resistance, for measuring the difference of potential (E) in volts, between the terminals of the lamp.

The lamp is placed in a suitable photometer, and simultaneous readings of the candle power = (s), the current (C) and E.M.F. (E) are taken. Then, by Ohms' Law, $C = \frac{E}{R}$.

Then *Resistance Hot* (*R*) *in Ohms* of Lamp . . . . $= \frac{E}{C}$

Electrical Energy in Watts spent on Lamp . . $= E \times C$

Energy in Kilogram-metres " " . $= E \times C \times 0{\cdot}10192$

Energy in Horse-Power " " . . $= \frac{E \times C}{746}$

Candles per Horse-Power . . . . . . $= \frac{s \times 746}{E \times C}$

Heat units per Candle in Gramme degrees . . $= \frac{E \times C \times 0{\cdot}24}{s}$

In the case of Incandescent Lamps, the *resistance cold* (*r*) of lamp is best found by the Wheatstone bridge, using a very low battery power, say 1 or 2 cells, as the resistance falls quickly if the carbon filament becomes heated.*

c. **Dynamos.**—In testing the efficiency of a dynamo, the lamp (L) in Fig. 19 is replaced by resistance coils of German silver or iron wire, or better, by thin ribands of these metals, and the battery (B) by the dynamo. With different resistances in circuit, readings are taken on the galvanometers. At the same time, the mechanical energy transmitted to the dynamo by belt or otherwise, is measured by a suitable dynamometer.

If (P) = the horse-power transmitted to the dynamo, and $\left(\frac{E \times C}{746}\right)$ = the electrical energy or work done on the resistance coil or external circuit, *i.e.*, the useful electrical horse-power given out by dynamo,

Then the efficiency $= \frac{E \times C}{746 \times P}$. For example, see trial 1, Table XX., p. 64.

Where (C) = current through external circuit = 30·7, E = (C × R) = (30·7 × 3·31) = 101·6 volts, and (P) = 6·4.

$\therefore$ Percentage efficiency $= \frac{100 \times E \times C}{746 \times P} = 65{\cdot}3\,\%$.

---

* For tests of Incandescent Lamps, by Crookes, and also by Jamieson, see *Journal Society Telegraph Engineers*, Vol. XI., No. 42; for "Arc Lamps," see *Engineering*, Nov. 17, 1882.

d. **Secondary Batteries or Accumulators.**—In charging secondary batteries, the battery to be charged replaces (L), and a dynamo, if used, takes the place of (B) in Fig. 19. Readings are taken for (C) and (E) at frequent intervals. From these the energy of charging current is found in Watts. In estimating the total work done in charging, time must be taken into account.

In testing the discharging, the battery takes the place of (B), and resistance coils or lamps that of (L) in Fig. 19. (C) and (E) are noted, and the energy, as well as total work done in Watts, obtained as before.

$$\therefore \text{ The efficiency of the secondary battery} = \frac{\text{the total work given out}}{\text{the total work put in}}.$$

The [illegible] [illegible]
divided [illegible]
[illegible]

The total work done in charging and discharging may also be measured by a suitable voltameter joined up as a shunt to the secondary battery, so as to pass a known fraction of the current through it (see pages 5, 6)*

e. **Transmission of Power.**—The efficiency of the transmission of power by electricity may be tested without the aid of electrical apparatus by simply attaching suitable dynamometers† to the generator and motor, and taking simultaneous readings.

Let P_1 = the power applied to generator, and P_2 = the power given out by motor. Then the percentage efficiency $= \frac{100\,P_2}{P_1}$. If, however, we wish to test the system electrically, let the generator replace (B) and the motor (L) in Fig. 19. Attach a potential galvanometer to the terminals of the generator, and place one current galvanometer at each end close to generator and motor. Take simultaneous readings on all four galvanometers. We have, whatever the length and insulation of line wire may be, E_1 and E_2 = E, M, F in volts; C_1 and C_2 = current in amperes at generator and motor respectively.

Then

E_1C_1 = power given out by generator in Watts.
E_2C_2 = ,, received by motor ,,

$$\text{The electrical efficiency of the system} = \frac{E_2C_2}{E_1C_1}.$$

If we wish the motor to give out power most rapidly, the above efficiency will be equal to *one-half*; but if we wish it to do work most economically, then $\frac{E_2C_2}{E_1C_1}$ must be a maximum $(=\frac{E_2}{E_1}$ if the insulation of the line wire be perfect and $C_1 = C_2$, when only one current galvanometer is required in circuit).

The ratio of the speeds of motor and generator should not be depended upon as a test of their efficiency.

---

* Professor Blyth, Glasgow, has perfected a current meter embodying this principle.

† For a complete description of Professors Ayrton and Perry's Galvanometers for Strong Currents, Photometer, and Power Dynamometer; also Siemens's Dynamometer and Electro-Dynamometer, see *Journal Society Telegraph Engineers*, Vol. XI., No. 43; also *Electrical Review*, 1882.

f. SIR WM. THOMSON'S GRADED GALVANOMETERS.

FOR MEASURING THE ELECTRO-MOTIVE FORCES AND CURRENTS IN ELECTRIC-LIGHTING OR DYNAMO CIRCUITS, OR WHEN CHARGING AND DISCHARGING SECONDARY CELLS, &C.*

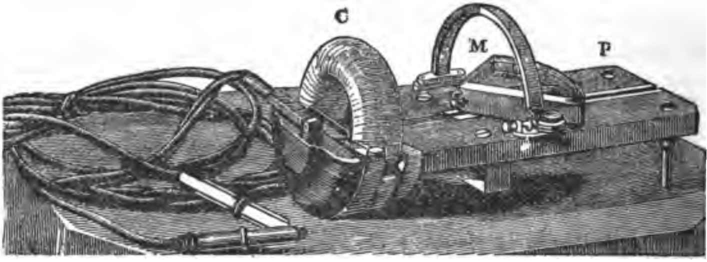


Fig. 20.

The **Potential Galvanometer** (Fig. 20) consists of a high resistance coil C, fixed to a wooden platform P, and a magnetometer M. The coil C contains about 7000 turns, or over 2000 yards of German silver wire of No. 32 B.W.G., and has a resistance of fully 6000 ohms. The platform P supports the coil and the magnetometer. The magnetometer consists of a quadrantal-shaped brass box, with a mirror bottom and glass cover, inside which a light system of magnetic needles and aluminium index or pointer is pivoted by means of a sapphire cap resting on an iridium point. The sensibility of the instrument is altered by putting the magnetometer nearer to or farther from the coil. The sensibility can be further varied by means of a semi-circular magnet placed over the magnetometer, as shown in the figure. The intensity of the field produced by this magnet is determined and painted on it, with the date of determination. This magnet renders the instrument less liable to disturbances due to other magnets, or to iron, or dynamos, in its neighbourhood. A scale is engraved on the platform P, the number at any division of which indicates the number of divisions the magnetometer needle will be deflected by one volt when it is in a magnetic field of C.G.S. unit intensity, and when the front of the magnetometer box is at that division.

To find the *volts* corresponding to any given deflection of the needle—

Rule.—*Multiply the number of divisions in the deflection by the intensity of the field, and divide by the number at the division exactly under the front of the magnetometer on the platform scale.*

---

*These instruments are illustrated in Figures 20 and 21, which are engravings from photographs of the instruments.

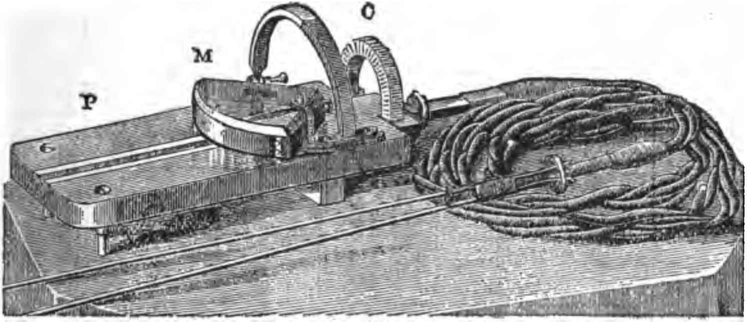


Fig. 21.

The **Current Galvanometer** (Fig. 21) is, with the exception of the coil, identical in every respect with the potential galvanometer. The coil in this instrument consists of a few turns, or of a single turn, of thick copper strip, and is capable of conveying very strong currents (100 amperes in the ordinary instruments).

To find the number of *amperes* corresponding to any particular deflection with this instrument—

Rule.—*Multiply the number of divisions in the deflection by the intensity of the field, and divide by the number at the division exactly under the front of the magnetometer on the platform scale.*

Directions applicable to both Instruments.—These instruments should be so placed that when no current is flowing in the coil, and no magnet is near the magnetometer, the index points to zero. When the semi-circular magnet is used on the magnetometer, the intensity of the field is nearly equal to the number on the magnet plus ·17 for the intensity of the earth's field in the British Islands. If the earth's field alone be used, its intensity at the place of observation must be known. It may be taken from the Chart of Horizontal Force, of the Admiralty Compass Manual.

A very convenient set of electrodes and spring contact clips, as shown in the Figures 20 and 21, is supplied along with each of these instruments, whereby the galvanometers may be quickly brought into or cut out of any electric circuit without disturbing the current in that circuit.

TABLE XX.—*g.* CROMPTON-BURGIN MACHINE.

TRIALS WITH HORIZONTAL SHUNT MACHINE, AT CHELMSFORD, June 24, 1882.

Number of Trial.	Speed. Revolutions per minute.	Resistance in (Ohms)		Current in (Ampères)			E. M. F. (Volts)		Percentage of			Horse-Power transmitted to Dynamo by belt.	Total Electrical Horse-Power.	Useful Electrical Horse-Power.	Percentage Efficiency or °/o of useful Electrical H.-P. to H.-P. transmitted by belt.
		External Circuit.	Total.	Bobbin.	Field Magnets.	External Circuit.	In Bobbin.	At Brushes.	Work lost in Bobbin.	Work lost in Field Magnets.	Work done in External Circuit.				
1	1450	3·310	3·055	38·70	8·00	30·70	118	97	17·8	14·6	67·6	6·40	6·15	4·16	65·0
1A	1500	2·335	2·455	45·74	7·40	38·34	113	88	22·1	11·1	66·8	7·10	6·90	4·60	65·0
2	1400	1·822	2·100	51·62	7·00	44·62	108	80	26·0	9·2	64·8	7·48	7·49	4·86	65·0
3	1520	1·822	2·095	52·90	6·90	46·00	110	82	25·8	8·5	65·7	8·82	7·80	5·18	58·7
4	1420	1·822	2·095	53·25	6·60	46·65	111	82	25·9	7·8	66·3	8·20	7·92	5·30	64·6
5	1420	3·320	3·605	30·20	1·80	28·40	111	92	15·0	4·1	81·9	4·55	4·40	3·60	79·0
6	1480	3·320	3·605	30·20	1·80	28·40	111	92	15·0	4·1	81·9	4·54	4·40	3·60	79·1
7	1630	2·470	2·875	39·30	1·86	37·44	113	92	18·9	3·3	77·8	6·44	5·92	4·60	71·3
8	1660	5·890	5·705	23·24	2·24	21·00	132	120	9·5	6·7	83·8	4·50	4·15	3·47	77·0
9	1650	5·890	5·705	23·24	2·24	21·00	132	120	9·5	6·7	83·8	4·27	4·15	3·47	81·3
10	1760	2·380	2·558	37·30	1·80	35·50	95	84	11·7	3·8	84·5	5·04	4·75	4·02	80·0
11	1800	2·380	2·558	39·34	1·90	37·44	100	88	11·5	3·8	84·7	5·44	5·30	4·50	82·7
12	1820	3·360	3·418	29·10	1·90	27·20	99	91	8·8	5·2	86·0	4·75	3·85	3·32	70·0
13	1800	4·46	4·338	21·95	1·90	20·05	95	88	6·9	7·3	85·8	3·99	2·79	2·40	60·0

Trials 1 to 4 with Type C_2 Machine. Bobbin, 0·545 ohms. Field Magnets, 2 in series. Resistance, 10·5 ohms.
" 5 to 9 " C_3 " " 0·545 " " 4 " " 42 "
" 10 to 13 " C_4 " " 0·298 " " all " " 42 "

NEW BOOKS AND NEW EDITIONS

PUBLISHED AND FOR SALE BY

THE INDUSTRIAL PUBLICATION CO.,

New York.

Any of these books will be sent to any part of the world on receipt of price. Canadian bills and fractional currency received at par. British postage stamps received at the rate of two cents for one penny. U. S. postage stamps received for fractional parts of a dollar.

New editions of our large catalogue are issued from time to time, and will be sent free to any address. ☞ LIBERAL TERMS TO AGENTS.

Trade "Secrets" and Private Recipes.

A Collection of Recipes, Processes and Formulæ that have been offered for sale at prices varying from 25 cents to $500. With Notes, Corrections, Additions and Special Hints for Improvements. Edited by JOHN PHIN, assisted by an experienced and skilful Pharmacist. Cloth, Gilt Title, - - 60c.

This work was prepared by the author for the purpose of collecting and presenting in a compact form all those recipes and so-called "trade secrets" which have been so extensively advertised and offered for sale. It is not by any means a clap-trap book, though it exposes many clap-traps. It contains a large amount of valuable information that cannot be readily found elsewhere, and it gives not only the formulæ, etc., for manufacturing an immense variety of articles, but important and trustworthy hints as to the best way of making money out of them. Even as a book of recipes it is worth more than its price to any one who is interested in the subjects on which it treats.

The Workshop Companion. Part II. (*Nearly Ready.*)

A Collection of Useful and Reliable Recipes, Rules, Processes, Methods, Wrinkles and Practical Hints. For the Household and the Shop. Neatly bound. Paper, 35c. Cloth, - - - - - - - - - - - 60c.

The extraordinary number which has been sold of the First Part of the "Workshop Companion," proves conclusively that such a little work was needed. Having received frequent inquiries for information upon subjects which were not discussed in the First Part, we have had a Second Part prepared for the purpose of supplying the information thus called for. The Second Part has been edited with the same care and thoroughness which did so much towards rendering Part I. a favorite with every worker. The best sources of knowledge have been consulted, and the more important articles have been confided to the hands of specialists of well-known ability.

The two parts will also be issued in one volume, printed on extra paper, and handsomely bound in cloth, with gilt stamp, under the title of THE PRACTICAL ASSISTANT. Price, - - - - - - - - - . - - - - $1.00

PRACTICAL BOOKS FOR PRACTICAL MEN.

The Steel Square and Its Uses. By Hodgson.

Second and Enlarged Edition, - - - - - - - - - - $1.00

This is the only complete work on The Steel Square and Its Uses ever published. It is thorough, exhaustive, clear and easily understood. Confounding terms and scientific phrases have been religiously avoided where possible, and everything in the book has been made so plain that a boy twelve years of age, possessing ordinary intelligence, can understand it from end to end.

The new edition is illustrated with over seventy-five wood cuts, showing how the Square may be used for solving almost every problem in the whole Art of Carpentry.

Stair-Building Made Easy.

Being a Full and Clear Description of the Art of Building the Bodies, Carriages and Cases for all kinds of Stairs and Steps. Together with Illustrations showing the Manner of Laying Out Stairs, Forming Treads and Risers, Building Cylinders, Preparing Strings, with Instructions for Making Carriages for Common, Platform, Dog-Legged, and Winding Stairs. To which is added an Illustrated Glossary of Terms used in Stair-Building, and Designs for Newels, Balusters, Brackets Stair-Mouldings, and Sections of Hand-Rails. By FRED. T. HODGSON. Cloth, Gilt, - - - - - - - $1.00

This work takes hold at the very beginning of the subject, and carries the student along by easy stages, until the entire subject of Stair-Building has been unfolded, so far as ordinary practice can ever require. This book and the one on HAND-RAILING, described below, cover nearly the whole subject of STAIR-BUILDING.

A New System of Hand-Railing.

Or, How to Cut Hand-Railing for Circular and other Stairs, Square from the Plank, without the aid of a Falling Mould. The System is New, Novel, Economic, and Easily Learned. Rules, Instructions, and Working Drawing for Building Rails for Seven Different Kinds of Stairs are given. By AN OLD STAIR-BUILDER. Edited and Corrected by FRED. T. HODGSON. Cloth, Gilt, - - - - - - - - - - - - - - $1.00

The Workshop Companion.

A Collection of Useful and Reliable Recipes, Rules, Processes, Methods, Wrinkles and Practical Hints for the Household and the Shop. Neatly Bound. - - - - - - - - - - - - - - - - 35c.

This is a book of 164 closely printed pages, forming a Dictionary of Practical Information, for Mechanics, Amateurs, Housekeepers, Farmers, Everybody. It is not a mere collection of newspaper clippings, but a series of original treatises on various subjects, such as Alloys, Cements, Inks, Steel, Signal Lights, Polishing Materials, and the art of Polishing Wood, Metals, etc.; Varnishes, Gilding, Silvering, Bronzing, Lacquering, and the working of Brass, Ivory, Alabaster, Iron, Steel, Glass, etc.

Drawing Instruments.

Being a Treatise on Draughting Instruments, with Rules for their Use and Care, Explanations of Scale, Sectors and Protractors. Together with Memooranda for Draughtsmen, Hints on Purchasing Paper, Ink, Instruments, Pencils, etc. Also a Price List of all materials required by Draughtsmen. Illustrated with Twenty-four Explanatory Illustrations. By FRED. T. HODGSON. Paper, - - - - - - - - - - - - - 25c.

Practical Carpentry.

Illustrated by Over 300 Engravings. Being a Guide to the Correct Working and Laying Out of all kinds of Carpenters' and Joiners' Work. With the solutions of the various problems in Hip-Roofs, Gothic Work, Centering, Splayed Work, Joints and Jointing, Hinging, Dovetailing, Mitering, Timber Splicing, Hopper Work, Skylights, Raking Mouldings, Circular Work, etc., etc., to which is prefixed a thorough treatise on "Carpenter's Geometry." By FRED. T. HODGSON, author of "The Steel Square and Its Uses," "The Builder's Guide and Estimator's Price Book," "The Slide Rule and How to Use It," etc., etc. Cloth, Gilt, - - - - - - - - - - - $1.00

This is the most complete book of the kind ever published. It is thorough, practical and reliable, and at the same time is written in a style so plain that any workman or apprentice can easily understand it.

Hand Saws.

Their Use, Care and Abuse. How to Select and How to File Them. By FRED. T. HODGSON, author of "The Steel Square and Its Uses," "The Builder's Guide and Estimator's Price Book," "Practical Carpentry," etc., etc. Illustrated by Over 75 Engravings. Being a Complete Guide for Selecting. Using and Filing all kinds of Hand Saws, Back Saws, Compass and Key-hole Saws, Web, Hack and Butcher's Saws; showing the Shapes, Forms, Angles, Pitches and Sizes of Saw Teeth suitable for all kinds of Saws, and for all kinds of Wood, Bone, Ivory and Metal; together with Hints and Suggestions on the choice of Files, Saw Sets, Filing Clamps, and other matters pertaining to the care and management of all classes of hand and other small saws. Cloth, Gilt, - - - - - - - - - - - $1.00

The work is intended more particularly for operative Carpenters, Joiners, Cabinet Makers, Carriage Builders and Wood Workers generally, amateurs or professionals.

Plaster: How to Make, and How to Use.

Illustrated with numerous engravings in the text, and Three Plates, giving some Forty Figures of Ceilings, Centrepieces, Cornices, Panels, and Soffits. Being a complete guide for the plasterer, in the preparation and application of all kinds of Plaster, Stucco, Portland Cements, Hydraulic Cements, Lime of Tiel, Rosendale and other Cements. To which is added an Illustrated Glossary of Technical Terms used by plasterers, with hints and suggestions regarding the working, mixing and preparation of scagliola and colored mortars of various kinds. Cloth, Gilt, - - - - - - - - $1.00

Just the book for Plasterers, Bricklayers, Masons, Builders, Architects and Engineers.

The Builder's Guide and Estimator's Price Book.

Being a Compilation of Current Prices of Lumber, Hardware, Glass, Plumbers' Supplies, Paints, Slates, Stones, Limes, Cements, Bricks, Tin, and other Building Materials; also, Prices of Labor, and Cost of Performing the Several Kinds of Work Required in Building. Together with Prices of Doors, Frames, Sashes, Stairs, Mouldings, Newels, and other Machine Work. To which is appended a large number of Building Rules, Data, Tables, and Useful Memoranda, with a Glossary of Architectural and Building Terms. By FRED. T. HODGSON, Editor of "The Builder and Wood-Worker," Author of "The Steel Square and Its Uses," etc., etc. 12mo., Cloth, - $2.00

Easy Lessons; or, The Stepping Stone to Architecture.

Consisting of a Series of Questions and Answers Explaining in Simple Language the Principles and Progress of Architecture from the earliest times. By Thomas Mitchell. Illustrated by nearly 150 Engravings. New Edition with American additions, - - - - - - - - - 50c.

Architecture is not only a Profession and an Art, but an important branch of every liberal education. No person can be said to be well educated who has not some knowledge of its general principles and of the characteristics of the different styles. The present work is probably the best architectural text-book for beginners ever published. The numerous illustrative engravings make the subject very simple and prevent all misunderstanding. It tells about the different styles, their peculiar features, their origin and the principles that underlie their construction.

Buck's Cottage and Other Designs.

Just the book you want if you are going to build a cheap and comfortable home. It shows a great variety of cheap and medium-priced cottages, besides a number of useful hints and suggestions on the various questions liable to arise in building, such as selection of site, general arrangement of the plans, sanitary questions, etc. Cottages costing from $500 to $5,000 are shown in considerable variety, and nearly every taste can be satisfied. Forty designs for fifty cents. Paper, - - - - - - - - - 50c.

The information on site, general arrangement of plan, sanitary matters, etc., etc., is worth a great deal more than the cost of the book.

Water-Closets.

A Historical, Mechanical and Sanitary Treatise. By Glenn Brown, Architect; Associate American Institute of Architects. Neatly Bound in Cloth, with Gilt Title, - - - - - - - - - - - - - - - $1.00

This book contains over 250 Engravings, drawn expressly for the work by the author. The drawings are so clear that the distinctive features of every device are easily seen at a glance, and the descriptions are particularly full and thorough. The paramount importance of this department of the construction of our houses renders all comment upon the value of such a work unnecessary.

Hints and Aids to Builders.

Hints and Aids in Building and Estimating. Gives Hints, Prices, tells how to Measure, explains Building Terms, and, in short, contains a fund of information for all who are interested in building. Paper, - - - - 25c.

Common Sense in the Poultry Yard.

A Story of Failures and Successes. Including a full account of 1,000 Hens and What They Did. With a complete description of the Houses, Coops, Fences, Runs, Methods of Feeding, Breeding, Marketing, etc., etc. And Many New Wrinkles and Economical Dodges. By J. P. Haig. With numerous illustrations. 12mo., Cloth, Gilt, - - - - - - $1.00

A most interesting narrative, which embodies the actual experience of many years in the keeping of poultry in large and small numbers.

Hints for Cabinet Makers, Upholsterers, and Furniture Men.

Hints and Practical Information for Cabinet-Makers, Upholsterers, and Furniture Men generally. Together with a description of all kinds of Finishing, with full directions therefor, Varnishes, Polishes, Stains for Wood, Dyes for Wood, Gilding and Silvering, Receipts for the Factory, Lacquers, Metals, Marbles, etc.; Pictures, Engravings, etc.; Miscellaneous. This work contains an immense amount of the most useful information for those who are engaged in Manufacture, Superintendence, or Construction of Furniture or Wood Work of any kind. It is one of the Cheapest and Best Books ever published, and contains over 1,000 Hints, Suggestions, Methods, and Descriptions of Tools, Appliances and Materials. All the Recipes, Rules, and Directions have been carefully Revised and Corrected by Practical Men of great experience, so that they will be found thoroughly trustworthy. Cloth, Gilt, - - - - - - - - - - - - - - - - $1.00

Mechanical Draughting.

The Student's Illustrated Guide to Practical Draughting. A series of Practical Instructions for Machinists, Mechanics, Apprentices, and Students at Engineering Establishments and Technical Institutes. By T. P. PEMBERTON, Draughtsman and Mechanical Engineer. Illustrated with numerous engravings. Cloth, Gilt, - - - - - - - - - - - $1.00

This is a simple but thorough book, by a draughtsman of twenty-five years' experience. It is intended for beginners and self-taught students, as well as for those who pursue the study under the direction of a teacher.

Lectures in a Workshop.

By T. P. PEMBERTON, formerly Associate Editor of the "Technologist;" Author of "The Student's Illustrated Guide to Practical Draughting." With an appendix containing the famous papers by Whitworth "On Plane Metallic Surfaces or True Planes;" "On an Uniform System of Screw Threads;" "Address to the Institution of Mechanical Engineers, Glasgow;" "On Standard Decimal Measures of Length." Cloth, Gilt, - - - $1.00

We have here a sprightly, fascinating book, full of valuable hints, interesting anecdotes and sharp sayings. It is not a compilation of dull sermons or dry mathematics, but a live, readable book. The papers by Whitworth, now first made accessible to the American reader, form the basis of our modern systems of accurate work.

How to Use The Microscope.

By JOHN PHIN. Fifth Edition. Greatly enlarged, with over eighty Illustrations in the Text, and six full page Engravings, printed on heavy tint paper. Cloth, Gilt, - - - - - - - - - - - - - $1.00

This is not a book describing *what may be seen* by the microscope, but a simple and practical work, telling how to use the instrument in its application to the arts. It has been prepared for the use of those who, having no knowledge of the use of the microscope, or, indeed, of any scientific apparatus, desire simple and practical instruction in the best methods of managing the instrument and preparing objects.

The Engineer's Slide Rule and Its Applications.

A Complete Investigation of the Principles upon which the Slide Rule is Constructed, together with the Method of its Application to all the Purposes of the Practical Mechanic. By William Tonkes. - - 25 cents.

Rhymes of Science: Wise and Otherwise.

By O. W. Holmes, Bret Harte, Ingoldsby, Prof. Forbes, Prof. J. W. McQ. Rankine, Hon. R. W. Raymond, and others. With Illustrations. Cloth, Gilt Title, 50 cents.

We advise all our readers into whose souls the sunlight of fun ever enters to purchase this little book. "Making light of *cereous* things" has been said, by a high authority to be "a *wicked* profession," but the genius which can balance the ponderosity of an ichthyosaur upon the delicate point of a euphonious rhyme, or bear aloft a bulky leptorhyncus on the sparkling foam of a soul-stirring love ditty, is worthy—worthy of a purchaser.—*Philadelphia Medical News.*

Instruction in the Art of Wood Engraving.

A Manual of Instruction in the Art of Wood Engraving; with a Description of the Necessary Tools and Apparatus, and Concise Directions for their Use; Explanation of the Terms Used, and the Methods Employed for Producing the Various Classes of Wood Engravings. By S. E. Fuller. Fully Illustrated with Engravings by the author, separate sheets of engravings for transfer and practice being added. New Edition, Neatly Bound, - - - - - - 50 cents.

What to Do in Case of Accident.

What to Do and How to Do It in Case of Accident. A Book for Everybody. 12mo., Cloth, Gilt Title, 50 cents.

This is one of the most useful books ever published. It tells exactly what to do in case of accidents, such as Severe Cuts, Sprains, Dislocations, Broken Bones, Burns with Fire, Scalds, Burns with Corrosive Chemicals, Sunstroke, Suffocation by Foul Air, Hanging, Drowning, Frost-Bite, Fainting, Stings, Bites, Starvation, Lightning, Poisons, Accidents from Machinery and from the Falling of Scaffolding, Gunshot Wounds, etc., etc. It ought to be in every house, for young and old are liable to accident, and the directions given in this book might be the means of saving many a valuable life.

A New Book for Bee-Keepers.

A Dictionary of Practical Apiculture, giving the correct meaning of nearly Five Hundred Terms, according to the usage of the best writers. Intended as a Guide to Uniformity of Expression amongst Bee-Keepers. With Numerous Illustrations, Notes, and Practical Hints. By JOHN PHIN, Author of "How to Use the Microscope," etc. Editor of the "Young Scientist." Price, Cloth, Gilt, . - - - - - - - - - - - 50 cts.

This work gives not only the correct meaning of five hundred different words, specially used in bee-keeping, but an immense amount of valuable information under the different headings. The labor expended upon it has been very great, the definitions having been gathered from the mode in which the words are used by our best writers on bee-keeping, and from the Imperial, Richardson's, Skeat's, Websters, Worcester's and other English Dictionaries. The technical information relating to matters connected with bee-keeping has been gathered from the Technical Dictionaries of Brande, Muspratt, Ure, Wagner, Watts, and others. Under the heads *Bee*, *Comb*, *Glucose*, *Honey*, *Race*, *Species*, *Sugar*, *Wax* and others, it brings together a large number of important facts and figures which are now scattered through our bee-literature, and through costly scientific works, and are not easily found when wanted. Here they can be referred to at once under the proper head.

How to Become a Good Mechanic.

Intended as a Practical Guide to Self-taught Men; telling What to Study; What Books to Use; How to Begin; What Difficulties will be Met; How to Overcome Them. In a word, how to carry on such a Course of Self-instruction as will enable the Young Mechanic to rise from the bench to something higher. Paper, - - - - - - - - - - - - - - 15 cts.

This is not a book of "goody-goody" advice, neither is it an advertisement of any special system, nor does it advocate any hobby. It gives plain, practical advice in regard to acquiring that knowledge which alone can enable a young man engaged in any profession or occupation connected with the industrial arts to attain a position higher than that of a mere workman.

Cements and Glue.

A Practical Treatise on the Preparation and Use of all Kinds of Cements, Glue, and Paste. By JOHN PHIN, Editor of the "Young Scientist" and the "American Journal of Microscopy." Stiff Covers, - - - 25 cts.

Hints for Painters, Decorators and Paperhangers.

Being a selection of Useful Rules, Data, Memoranda, Methods and Suggestions for House, Ship, and Furniture Painting, Paperhanging, Gilding, Color Mixing, and other matters Useful and Instructive to Painters and Decorators. Prepared with Special Reference to the Wants of Amateurs. By an OLD HAND. - - - - - - - - - - - - - 25 cts.

Any of these books will be sent post paid to any address receipt of price.

The Workshop Companion.

A Collection of Useful and Reliable Recipes, Rules, Processes, Methods, Wrinkles and Practical Hints for the Household and the Shop. Neatly Bound - - - - - - - - - - - - - - 35c.

This is a book of 164 closely printed pages, forming a Dictionary of Practical Information, for Mechanics, Amateurs, Housekeepers, Farmers, Everybody. It is not a mere collection of newspaper clippings, but a series of original treatises on various subjects such as Alloys, Cements, Inks, Steel, Signal Lights, Polishing Materials, and the art of Polishing Wood, Metals, etc.; Varnishes, Gilding, Silvering, Bronzing, Lacquering, and the working of Brass, Ivory, Alabaster, Iron, Steel, Glass, etc.

Carpenter's and Joiner's Pocket Companion.

Containing Rules, Data and Directions for Laying Out Work and for Calculating and Estimating. Compiled by THOMAS MOLONEY, Carpenter and Joiner. Neatly Bound in Cloth, with Gilt Stamp and Red Edges, - 50 cts.

This is a compact and handy little volume, containing enough matter that is not easily found anywhere else to make it worth more than its price to every intelligent carpenter.

Hints for Painters, Decorators and Paperhangers.

Being a selection of Useful Rules, Data, Memoranda, Methods and Suggestions for House, Ship, and Furniture Painting, Paperhanging, Gilding, Color Mixing, and other matters Useful and Instructive to Painters and Decorators. Prepared with Special Reference to the Wants of Amateurs. By an OLD HAND, - - - - - - - - - - - - - - 25 cts.

Drawing Instruments.

Being a Treatise on Draughting Instruments, with Rules for their Use and Care, Explanations of Scale, Sectors and Protractors. Together with Memoranda for Draughtsmen, Hints on Purchasing Paper, Ink, Instruments, Pencils, etc. Also a Price List of all materials required by Draughtsmen. Illustrated with Twenty-four Explanatory Illustrations. By FRED. T. HODGSON. Paper, - - - - - - - - - - - - - - 25c.

Cements and Glue.

A Practical Treatise on the Preparation and Use of all kinds of Cements, Glue and Paste. By JOHN PHIN, author of "How to Use the Microscope." Paper, - - - - - - - - - - - - - - - - 25 cts.

Contains nearly 200 recipes for the preparation of Cements for almost every conceivable purpose.

Common Sense in the Poultry Yard	**$ .00**
What to Do in Case of Accident	**50c.**
How to Become a Good Mechanic	**15c**
Rhymes of Science: Wise and Otherwise	**50c.**
Shooting on the Wing	**75c.**
The Pistol, and How to Use It	**50c.**

Any of these books will be sent post paid to any address on receipt of price.

Shooting on the Wing.

Plain Directions for Acquiring the Art of Shooting on the Wing. With Useful Hints concerning all that relates to Guns and Shooting, and particularly in regard to the art of Loading so as to Kill. To which has been added several Valuable and hitherto Secret Recipes, of Great Practical Importance to the Sportsman. By an Old Gamekeeper.

12mo., Cloth, Gilt Title. - - - 75 cents.

The Pistol as a Weapon of Defence,

In the House and on the Road.

12mo., Cloth. - - - - - 50 cents.

This work aims to instruct the peaceable and law-abiding citizens in the best means of protecting themselves from the attacks of the brutal and the lawless, and is the only practical book published on this subject. Its contents are as follows: The Pistol as a Weapon of Defence.—The Carrying of Fire-Arms.—Different kinds of Pistols in Market; How to Choose a Pistol.—Ammunition, different kinds; Powder, Caps, Bullets, Copper Cartridges, etc.—Best form of Bullet.—How to Load.—Best Charge for Pistols.—How to regulate the Charge.—Care of the Pistol; how to Clean it.—How to Handle and Carry the Pistol.—How to Learn to Shoot.—Practical use of the Pistol; how to Protect yourself and how to Disable your antagonist.

Lightning Rods.

Plain Directions for the Construction and Erection of Lightning Rods. By John Phin, C. E., editor of "The Young Scientist," author of "Chemical History of the Six Days of the Creation," etc. Second Edition. Enlarged and Fully Illustrated.

12mo., Cloth, Gilt Title. - - - 50 cents.

This is a simple and practical little work, intended to convey just such information as will enable every property owner to decide whether or not his buildings are thoroughly protected. It is not written in the interest of any patent or particular article of manufacture, and by following its directions, any ordinarily skilful mechanic can put up a rod that will afford perfect protection, and that will not infringe any patent. Every owner of a house or barn ought to procure a copy.

Hours with a Three-Inch Telescope.

By Capt. William Noble, F. R. A. S., F. R. M. S., Honorary Associate of the Liverpool Astronomical Society, etc. 12mo., Cloth, - - $1.50

This book is even more elementary and practical than Webb's "Celestial Objects. It has been written to furnish the very beginner in observational astronomy with such directions as shall enable him to employ, to the greatest possible advantage, the kind of instrument with which he will, in all probability, at first provide himself.

Like our edition of Webb, the book has been made for us by the English publishers, and is in all respects the same as the English edition.

Celestial Objects for Common Telescopes.

By the Rev. T. W. Webb, M. A., F. R. A. S. Fourth Edition, Revised and Greatly Enlarged. Fully Illustrated with Engravings and a large Map of the Moon. Cloth, - - - - - - - - - - - - - $3.00

This edition has been made for us by the English publishers, and is in every respect the same as the English edition. The work itself is too well known to require commendation at our hands. No one that owns even the commonest kind of a telescope can afford to do without it.

"Many things deemed invisible to secondary instruments, are plain enough to one who knows how to see them."—Smyth.

"When an object is once discerned by a superior power, an inferior one will suffice to see it afterwards."—Sir W. Herschell.

The Sun.

A Familiar Description of His Phenomena. By the Rev. Thomas William Webb, M. A., F. R. A. S., author of "Celestial Objects for Common Telescopes." With Numerous Illustrations. Cloth, - - - - - 40c.

This work gives in a delightfully popular style an account of the most recent discoveries in regard to the Sun. It is very freely illustrated.

Chemical History of the Six Days of Creation.

By John Phin, author of "How to Use the Microscope." 12mo., Cloth 75c.

In this volume an attempt is made to trace the evolution of our globe from the primeval state of nebulous mist, "without form and void," and existing in "darkness," or with an entire absence of the manifestations of the physical forces, to the condition in which it was fitted to become the habitation of man. While the statements and conclusions are rigidly scientific, it gives some exceedingly novel views of a rather hackneyed subject.

Microscope Objectives.

The Angular Aperture of Microscope Objectives. By Dr. George E. Blackham. 8vo., Cloth. Eighteen full page illustrations printed on extra fine paper, - - - - - - - - - - - - - - - - - - $1.25

This is the elaborate paper on Angular Aperture, read by Dr. Blackham before the Microscopical Congress, held at Indianapolis.

Marvels of Pond Life.

A Year's Microscopic Recreations Among the Polyps, Infusoria, Rotifers, Water Bears and Polyzoa. By Henry J. Slack, F. G. S., F. R. M. S., etc. Second Edition. Seven full page Plates and Numerous Wood Engravings in the text. 12mo., Cloth, - - - - - - - - - - - $1.00

Section Cutting.

A Practical Guide to the Preparation and Mounting of Sections for the Microscope; Special Prominence being given to the Subject of Animal Sections By Sylvester Marsh. Reprinted from the London edition. With Illustrations. 12mo., Cloth, Gilt Title. · 75 cents.

This is undoubtedly the most thorough treatise extant upon section cutting in all its details. The American edition has been greatly enlarged by valuable explanatory notes, and also by extended directions, illustrated with engravings, for selecting and sharpening knives and razors.

A Book for Beginners with the Microscope.

Being an abridgment of "Practical Hints on the Selection and Use of the Microscope." By John Phin. Fully illustrated, and neatly and strongly bound in boards. 30 cts.

This book was prepared for the use of those who, having no knowledge of the use of the microscope, or, indeed, of any scientific apparatus, desire simple and practical instruction in the best methods of managing the instrument and preparing objects.

How to Use the Microscope.

"Practical Hints on the Selection and Use of the Microscope." Intended for Beginners. By John Phin, Editor of the "American Journal of Microscopy." Fourth Edition. Greatly enlarged, with over 80 engravings in the text, and 6 full-page engravings, printed on heavy tint paper. 12mo., cloth, gilt title, - $1.00

The Microscope.

By Andrew Ross. Fully Illustrated. 12mo., Cloth, Gilt Title. - - - - - 75 cents.

This is the celebrated article contributed by Andrew Ross to the "Penny Cyclopædia," and quoted so frequently by writers on the Microscope Carpenter and Hogg, in the last editions of their works on the Microscope, and Brooke, in his treatise on Natural Philosophy, all refer to this article as the best source for full and clear information in regard to the principles upon which the modern achromatic Microscope is constructed. It should be in the library of every person to whom the Microscope is more than a toy. It is written in simple language, free from abstruse technicalities.

FOURTH EDITION. Greatly Enlarged, with over 80 *illustrations in the Text and* 6 *full page Engravings, printed on Heavy Tint Paper.* 1 *Vol.* 12*mo.*, 240 *pages. Neatly Bound in Cloth, Gilt Title. Price* $1.00.

HOW TO USE THE MICROSCOPE.

A SIMPLE AND PRACTICAL BOOK, INTENDED FOR BEGINNERS.

By JOHN PHIN,

Editor of "The American Journal of Microscopy."

CONDENSED TABLE OF CONTENTS.

The Microscope.—What it Is; What it Does; Different Kinds of Microscopes; Principles of its Construction; Names of the Different Parts.

Simple Microscopes.—Hand Magnifiers; Doublets; Power of Two or More Lenses When Used Together; Stanhope Lens; Coddington Lens; Achromatic Doublets and Triplets; Twenty-five Cent Microscopes—and How to Make Them; Penny Microscopes, to Show Eels in Paste and Vinegar.

Dissecting Microscopes.—Essentials of a Good Dissecting Microscope.

Compound Microscopes.—Cheap Foreign Stands; The Ross Model; The Jackson Model; The Continental Model; The New American Model; Cheap American Stands; The Binocular Microscope; The Binocular Eye-piece; The Inverted Microscope; Lithological Microscopes; The Aquarium Microscope; Microscopes for Special Purposes; "Class" Microscopes.

Objectives.—Defects of Common Lenses; Spherical Aberration; Chromatic do.; Corrected Objectives; Defining Power; Achromatism; Aberration of Form; Flatness of Field; Angular Aperture; Penetrating Power; Working Distance; Immersion and "Homogeneous" Lenses; Duplex Fronts; French Triplets, etc., etc.

Testing Objectives.—General Rules; Accepted Standards—Diatoms, Ruled Lines, Artificial Star; Podura; Nobert's Lines; Möller's Probe Platte, etc., etc.

Selection of a Microscope.—Must be Adapted to Requirements and Skill of User; Microscopes for Botany; For Physicians; For Students.

Accessory Apparatus.—Stage Forceps; Forceps Carrier; Plain Slides; Concave Slides; Watch-Glass Holder; Animalcule Cage; Zoophyte Trough; The Weber Slide; The Cell-Trough; The Compressorium; Gravity Compressorium; Growing Slides; Frog Plate; Table; Double Nose-piece.

Illumination.—Sun-Light; Artificial Light—Candles, Gas, Lamps, etc., etc.

Illumination of Opaque Objects.—Bulls-Eye Condenser; Side Reflector; The Lieberkuhn; The Parabolic Reflector; Vertical Illuminators.

Illumination of Transparent Objects.—Direct and Reflected Light; Axial or Central Light; Oblique Light; The Achromatic Condenser; The Webster Condenser, and How to Use it; Wenham's Reflex Illuminator, and How to Use it; The Wenham Prism; The "Half-Button;" The Woodward Illuminator; Tolles' Illuminating Traverse Lens; The Spot Lens; The Parabolic Illuminator; Polarized Light.

How to Use the Microscope.—General Rules; Hints to Beginners.

How to Use Objectives of Large Aperture.—Collar-Correction, etc.

Care of the Microscope.—Should be Kept Covered; Care of Objectives; Precautions to be Used when Corrosive Vapors and Liquids are Employed; To Protect the Objectives from Vapors which Corrode Glass; Cleaning the Objectives; Cleaning the Brass Work.

Collecting Objects.—Where to Find Objects; What to Look for; How to Capture Them.

The Preparation and Examination of Objects.—Cutting Thin Sections of Soft Substances; Valentine's Knife; Sections of Wood and Bone; Improved Section Cutter; Sections of Rock; Knives; Scissors; Needles; Dissecting Pans and Dishes; Dissecting Microscopes; Separation of Deposits from Liquids; Preparing Whole Insects; Feet, Eyes, Tongues, Wings, etc., of Insects; Use of Chemical Tests; Liquids for Moistening Objects; Refractive Powers of Different Liquids; Iod-Serum; Artificial Iod-Serum; Covers for Keeping Out Dust; Errors in Microscopic Observations.

Preservative Processes.—General Principles; Preservative Media.

Apparatus for Mounting Objects.—Slides; Covers; Cells; Turn-Tables, etc.

Cements and Varnishes.—General Rules for Using.

Mounting Objects.—Mounting Transparent Objects Dry; in Balsam; in Liquids; Whole Insects; How to Get Rid of Air-Bubbles; Mounting Opaque Objects.

Finishing the Slides.—Cabinets; Maltwood Finder; Microscopical Fallacies.

A NEW SERIES OF PRACTICAL BOOKS.

WORK MANUALS.

The intention of the publishers is to give in this Series a number of small books which will give Thorough and Reliable Information in the plainest possible language, upon the

ARTS OF EVERYDAY LIFE.

Each volume will be by some one who is not only practically familiar with his subject, but who has the ability to make it clear to others. The volumes will each contain from 50 to 75 pages, will be neatly and clearly printed on good paper and bound in tough and durable binding. The price will be ***25 cents each, or five for One Dollar.***

The following are the titles of the volumes already issued. Others will follow at short intervals.

I. Cements and Glue.

A Practical Treatise on the Preparation and Use of All Kinds of Cements, Glue and Paste. By JOHN PHIN, Editor of the *Young Scientist* and the *American Journal of Microscopy.*

Every mechanic and householder will find this volume of almost everyday use. It contains nearly 200 recipes for the preparation of Cements for almost every conceivable purpose.

II. The Slide Rule, and How to Use It.

This is a compilation of Explanations, Rules and Instructions suitable for mechanics and others interested in the industrial arts. Rules are given for the measurement of all kinds of boards and planks, timber in the round or square, glaziers' work and painting, brickwork, paviors' work, tiling and slating, the measurement of vessels of various shapes, the wedge, inclined planes, wheels and axles, levers, the weighing and measurement of metals and all solid bodies, cylinders, cones, globes, octagon rules and formulæ, the measurement of circles, and a comparison of French and English measures, with much other information, useful to builders, carpenters, bricklayers, glaziers, paviors, slaters, machinists and other mechanics.

Possessed of this little Book and a good Slide Rule, mechanics might carry in their pockets some hundreds of times the power of calculation that they now have in their heads, and the use of the instrument is very easily acquired.

III. Hints for Painters, Decorators and Paperhangers.

Being a selection of Useful Rules, Data, Memoranda, Methods and Suggestions for House, Ship, and Furniture Painting, Paperhanging, Gilding, Color Mixing, and other matters Useful and Instructive to Painters and Decorators. Prepared with Special Reference to the Wants of Amateurs. By an Old Hand.

IV. Construction, Use and Care of Drawing Instruments.

Being a Treatise on Draughting Instruments, with Rules for their Use and Care, Explanations of Scales, Sectors and Protractors. Together with Memoranda for Draughtsmen, Hints on Purchasing Paper, Ink, Instruments, Pencils, etc. Also a Price List of all materials required by Draughtsmen. Illustrated with twenty-four Explanatory Illustrations. By FRED. T. HODGSON.

V. The Steel Square.

Some Difficult Problems in Carpentry and Joinery Simplified and Solved by the aid of the Carpenters' Steel Square, together with a Full Description of the Tool, and Explanations of the Scales, Lines and Figures on the Blade and Tongue, and How to Use them in Everyday Work. Showing how the Square may be Used in Obtaining the Lengths and Bevels of Rafters, Hips, Groins, Braces, Brackets, Purlins, Collar-Beams, and Jack-Rafters. Also, its Application in Obtaining the Bevels and Cuts for Hoppers, Spring Mouldings, Octagons, Diminished Styles, etc., etc. Illustrated by Numerous Wood-cuts. By FRED. T. HODGSON, Author of the "Carpenters' Steel Square."

Note.—**This work is intended as an elementary introduction for the use of those who have not time to study Mr. Hodgson's larger work on the same subject.**

THE WORKSHOP COMPANION.

A Collection of Useful and Reliable Recipes, Rules, Processes, Methods, Wrinkles, and Practical Hints,

FOR THE HOUSEHOLD AND THE SHOP.

CONTENTS.

Abyssinian Gold;—Accidents, General Rules;—Alabaster, how to work, polish and clean;—Alcohol;—Alloys, rules for making, and 26 recipes;—Amber, how to work, polish and mend;—Annealing and Hardening glass, copper, steel, etc.;—Arsenical Soap;—Arsenical Powder;—Beeswax, how to bleach;—Blackboards, how to make;—Brass, how to work, polish, color, varnish, whiten, deposit by electricity, clean, etc., etc.; —Brazing and Soldering;—Bronzing brass, wood, leather, etc.;—Burns, how to cure;—Case-hardening;—Catgut, how prepared;—Cements, general rules for using, and 56 recipes for preparing;—Copper, working, welding, depositing;—Coral, artificial;—Cork, working;—Crayons for Blackboards;—Curling brass, iron, etc.;—Liquid Cuticle;—Etching copper, steel, glass;—Eye, accidents to;—Fires, to prevent;—Clothes on Fire;—Fireproof Dresses;—Fly Papers;—Freezing Mixtures, 6 recipes;—Fumigating Pastils;—Gilding metal, leather, wood, etc.;—Glass, cutting, drilling, turning in the lathe, fitting stoppers, removing tight stoppers, powdering, packing, imitating ground glass, washing glass vessels, etc.;—Grass, Dry, to stain;—Guns, to make shoot close, to keep from rusting, to brown the barrels of, etc., etc.;—Handles, to fasten;—Inks, rules for selecting and preserving, and 34 recipes for;—Ink Eraser;—Inlaying;—Iron, forging, welding, case-hardening, zincing, tinning, do. in the cold, brightening, etc., etc.;—Ivory, to work, polish, bleach, etc.;—Javelle Water;—Jewelry and Gilded Ware, care of, cleaning, coloring, etc.;—Lacquer, how to make and apply;—Laundry Gloss;—Skeleton Leaves;—Lights, signal and colored, also for tableaux, photography, etc., 25 recipes;—Lubricators, selection of, 4 recipes for;—Marble, working, polishing, cleaning;—Metals, polishing;—Mirrors, care of, to make, pure silver, etc., etc.;—Nickel, to plate with without a battery;—Noise, prevention of;—Painting Bright Metals;—Paper, adhesive, barometer, glass, tracing, transfer, waxed, etc.;—Paper, to clean, take creases out of, remove water stains, mount drawing paper, to prepare for varnishing, etc , etc.;—Patina;—Patterns, to trace;—Pencils, indelible;—Pencil Marks, to fix;—Pewter;—Pillows for Sick Room, cheap and good;—Plaster-of-Paris, how to work;—Poisons, antidotes for, 12 recipes;—Polishing Powders, preparation and use of (six pages);—Resins, their properties, etc.;—Saws, how to sharpen;—Sieves;—Shellac, properties and uses of;—Silver, properties of, oxidized, old, cleaning, to remove ink stains from, to dissolve from plated goods, etc., etc.;—Silvering metals, leather, iron, etc.;—Size, preparation of various kinds of;—Skins, tanning and curing, do with hair on;—Stains, to remove from all kinds of goods;—Steel, tempering and working (six pages);—Tin, properties, methods of working;—Varnish, 21 recipes for;—Varnishing, directions for;—Voltaic Batteries;—Watch, care of;—Waterproofing, 7 recipes for;—Whitewash;—Wood Floors, waxing, staining, and polishing;—Wood, polishing;—Wood, staining, 17 recipes;—Zinc, to pulverize, black varnish for.

164 closely-printed pages, neatly bound. Sent by mail for 36 cents (postage stamps received).

NEW DESIGNS

FOR

Fret or Scroll Sawyers.

MR. F. T. HODGSON, whose admirable series of articles on the USE OF THE SCROLL SAW are now in course of publication in the YOUNG SCIENTIST, has prepared for us a series of

SEVENTEEN DESIGNS,

of which the following is a list:

No. 1.—This shows one side, back, and bottom, of a pen rack. It may be made of ebony, walnut, or other dark wood.

No. 2.—Design for inlaying drawer fronts, table tops, box lids, and many other things. It is a sumach leaf pattern.

No. 3.—Design for a thermometer stand. It may be made of any hard wood or alabaster. The method of putting together is obvious.

No. 4.—This shows a design for a lamp screen. The open part may be covered with tinted silk, or other suitable material, with some appropriate device worked on with the needle, or, if preferred, ornaments may be painted on the silk, etc.

No. 5.—A case for containing visiting cards. Will look best made of white holly.

No. 6.—A placque stand, it may be made of any kind of dark or medium wood.

No. 7.—A design for ornaments suitable for a window cornice. It should be made of black walnut, and overlaid on some light colored hard wood.

No. 8—A design for a jewel casket. This will be very pretty made of white holly and lined with blue velvet. It also looks well made of ebony lined with crimson.

No. 9.—Frame. Will look well made of any dark wood.

No. 10.—Frame. Intended to be made in pairs. Looks well made of white holly, with leaves and flowers painted on wide stile.

No. 11.—Horseshoe. Can be made of any kind of wood and used for a pen rack. When decorated with gold and colors, looks very handsome.

No. 12.—Design for a hinge strap. If made of black walnut, and planted on a white or oaken door, will look well.

No. 13.—Design for a napkin ring. May be made of any kind of hard wood.

No. 14.—Hinge strap for doors with narrow stiles.

No. 15.—Centre ornament for panel.

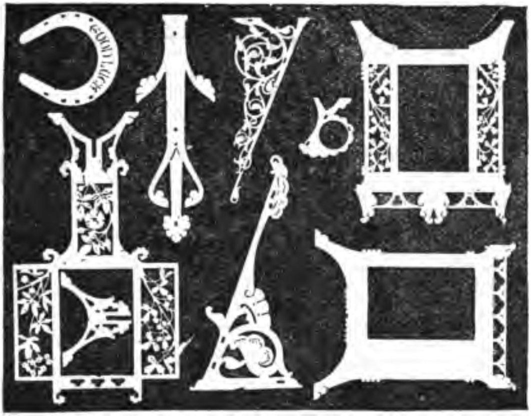
No. 16.—Corner ornament for panel.

No. 17.—Key-hole escutcheon.

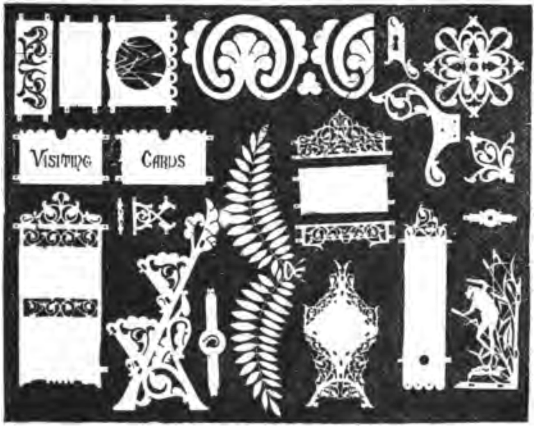
These designs we have had photo-lithographed and printed on good paper, so that the outlines are sharp, and the opposite sides of each design symmetrical. Common designs are printed from coarse wooden blocks, and are rough and unequal, so that it is often impossible to make good work from them.

The series embraces over forty different pieces, and designs of equal quality cannot be had for less than five, ten or fifteen cents each. We offer them for twenty-five cents for the set, which is an average price of only one cent and a half each.

Mailed to any address on receipt of price.



SHEET NO. 1.



SHEET NO. 2.

REDUCED FIGURES OF

NEW DESIGNS FOR FRET OR SCROLL SAWYERS.

SIZE OF SHEETS 28 BY 22 INCHES.

(For description see preceding page.)

This book should be returned to the Library on or before the last date stamped below.

A fine of five cents a day is incurred by retaining it beyond the specified time.

Please return promptly.

Eng 4938.89
Electrical rules, tables, tests and
Cabot Science 005453970
3 2044 091 856 849